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POULTRY HUSBANDRY

BY

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SECOND EDITION
SIXTH IMPRESSION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK AND LONDON
1938

PRINTED IN THE UNITED STATES OF AMERICA

THE MAPLE PRESS COMPANY, YORK, PA.

PREFACE

The purpose of this book is to convey to its readers some conception of the background of the poultry industry, the fundamental principles involved in various poultry practices, and up-to-date information concerning methods of poultry production. The more important economic factors in producing and marketing poultry products are given due consideration.

Success in poultry raising depends largely upon one's knowledge of the business and one's ability to produce and market poultry and poultry products efficiently. Fundamental principles must be understood to some extent at least before the most economical methods can be practiced intelligently. For this reason the major aspects of poultry production and marketing are discussed, first, with respect to principles involved and, second, with respect to practices to be followed.

The discussion of fundamental principles involved should stimulate further research concerning the problems raised. The results of the various lines of research work are reviewed, and selected lists of literature references are given, so that the investigator, teacher, and student each has a ready reference for review purposes.

The discussion of practices to be followed should be of considerable value to extension workers, farmers, and commercial poultrymen. Poultrymen everywhere should appreciate the fact that science is indeed a foundation or a background upon which they may develop more efficient practices in husbandry. This book is an attempt to integrate the facts of modern science for the benefit of the practical poultryman. The preparation of the book has been inspired in the spirit of rendering the greatest possible service to the poultry industry.

The author is deeply indebted to Dr. T. C. Byerly for reading the material in Chaps. II, V, VIII, and IX and to Professor James M. Gwin for reading Chaps. XI and XII. Both of these staff members of the University of Maryland Poultry Department offered a number of valuable suggestions which were incorporated in the text.

UNIVERSITY OF MARYLAND,
COLLEGE PARK, MD.,
June, 1938.

MORLEY A. JULL.

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POULTRY HUSBANDRY

CHAPTER I

THE BREEDS OF CHICKEN

From time immemorial, chickens have been closely associated with human interests in numerous ways. The ancestors of the domestic stocks were hunted for food, and the pugnacious character of the wild cock led to the development of the sport of cockfighting, which frequently had a remarkable influence on civilizations of bygone days.

In more recent times, poultry breeders of various nationalities have busily occupied themselves with domestic stocks in evolving plumage colorations in bewildering variety. Also, in many cases, body type and feather structure have been so altered as to demonstrate the relative plasticity of the original stock. What man has accomplished by breeding from selected variants has been shown by his success in developing the large number of breeds and varieties, each of which conforms to certain standards.

Origin of the Chicken.—The original habitat of the ancestor of modern breeds of chickens is south and central India, the Himalayan Terai, Assam, Burma, Ceylon, and throughout all the countries to the southward, on into Sumatra and Java with its string of lesser islands to the eastward. There are four known species of wild fowl, and they belong to the same genus called "Gallus," meaning a cock.

The four species are as follows: (1) *Gallus gallus* (Linneaus) or *Gallus bankiva*, the Red Junglefowl; (2) *Gallus lafayette* (Lesson), the Ceylon Junglefowl; (3) *Gallus sonnerati* (Temminck), the Gray Junglefowl; (4) *Gallus varius* (Griffith), the Javan Junglefowl. The Javan Junglefowl differs from the other three species in having a single-median wattle, a smooth-edged comb, truncated neck hackles, and an extra pair of rectrices, or tail feathers.

The general distribution of the four species is as follows: The Red Junglefowl is widely distributed through eastern India, Burma, Siam, and Sumatra; the Ceylon Junglefowl in Ceylon; the Gray Junglefowl in western and southern India; the Javan Junglefowl in Java and adjacent islands.

All four species will cross with one another, and the hybrids are more or less fertile among themselves. Also, from evidence supplied by

naturalists and investigators who have made crosses between each of the four wild species and domestic stocks, it appears that all hybrid progeny are fertile with the possible exception of the female offspring of the cross between the *Gallus varius* male and domestic females. Apparently most of the modern day breeds are descended from these four wild species.

It seems somewhat doubtful, however, if some of the modern breeds of Asiatic origin followed the same line of descent from the wild species as many of the Western European and American breeds that descended directly from the four wild species inhabiting India, Java, Siam, Burma, Ceylon, and Sumatra. In the Asiatic breeds, the Cochins, Brahmas, and Langshans, the long axis of the opening of the skull through which passes the spinal cord is perpendicular, whereas in the four wild species and in most other domestic breeds the opening is horizontal.

Early Influence of Cockfighting.—That the sport of cockfighting exercised a tremendous influence not only in the domestication of wild birds but also in the subsequent distribution of the fowl is amply demonstrated by the importance attached to the pastime by many human races. The literature of various nations contains many references to the sport, and it would appear that cockfighting had as much responsibility for the domestication of the fowl as demand for food and that the sport was chiefly instrumental in the widespread distribution that followed.

Early Distribution of the Chicken.—The antiquity of the domestic chicken in India probably dates back as far as about 3200 B.C., and in Egypt as far back as 1400 B.C. It is difficult to establish with any degree of exactness the time when the chicken was domesticated in India because the early records are not clear on this point. The domestication of the cock in China dates back to as early as 1400 B.C., although the chicken appears in the hieroglyphics in the tomb of Mera about 3200 B.C. The modern name for the bird, *ki* or *kai*, can be traced to the Chou Dynasty, which extended from 1122 to 249 B.C. *Ki* is defined in a very ancient dictionary as "the domestic animal which knows the time"; and in a glossary of the time of Confucius, it is found again.

From India, the cock moved northward and westward, against the line of Aryan invasion, and reached Bactria and Persia at a very early date. Judging by the part that the cock played in Persian religion and mythology, and the frequent reference to it in Zoroastrian literature, its advent must have considerably antedated 600 B.C.

In Grecian literature the first mention of the cock is by Theognia about 525 B.C. On the other hand, the image of the cock appeared on coins from the temple of Artemis at Ephesus at least 700 B.C.

Subsequent distribution of the fowl followed the line of the Iranian invasion, which carried the bird through Bactria and Persia on into Scythia and Europe, stretching across finally to the British Isles and

spreading down from Gaul into central Italy. Long before Greek colonists carried the bird to southern Italy, it had passed on to the northward and was being carried southward through Italy on the line of an independent advance. The first European distribution of the cock was overland rather than by sea or by coastal colonists. The Romans found it well established in Gaul, England, and among the Germans.

The distribution of the fowl southward began when the Greeks carried stocks southward to the Phoenician cities. Only at a late date, however, did the fowl become well established on the Syrian mainland. From the Medes and Persians, to whom it had been known since 1000

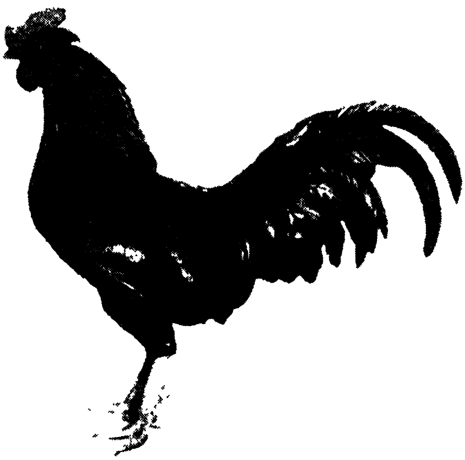


FIG. 1.—The *Gallus bankiva* species of wild fowl, the male of which is shown here, is regarded by many authorities as being the principal one of the four wild species from which modern breeds have descended. (*U. S. Dept. Agr.*)

B.C., it was taken to the Assyrians and Babylonians as early as 700 B.C. From the Aramaeans it was introduced to the Jews in Palestine about 200 B.C.

By the time of the Christian era it seems highly probable that the domestic fowl had spread itself over the western parts of Asia and the eastern parts of Europe. From these parts domestic fowls were readily transported to other countries including South Africa, Australia, Japan, Siberia, Russia, Scandinavian countries, and the Americas.

Poultry culture in the United States apparently had its beginnings in 1607, for this was the year of the first permanent English settlement in this country, 100 Englishmen having landed at Jamestown Island. During the first half of the seventeenth century in the United States

several importations of domestic fowl were made from England, various parts of Europe, and Asia. Interest in the breeding of poultry increased, and definite attempts were made to develop standards of excellence for the various breeds of chickens that were then being bred. In 1849 the first poultry show was held in America, and this gave an impetus to the development of standards for the various breeds.

MODERN BREEDS

From that time on, interest in the breeding of the various classes of poultry for exhibition purposes increased rapidly, until by 1873 there took place the first organized effort to place the breeding industry upon a stable basis. In that year there was organized the American Poultry Association, which had for its object the formulation and adoption of a standard of excellence to be used exclusively by poultry associations in awarding prizes on exhibition poultry. A complete standard was adopted for all the then recognized varieties of domestic and ornamental classes of poultry, and in 1874 the first "Standard of Perfection" was printed. Since that time, the "Standard," revised periodically, has served as the basis of guidance in breeding operations in developing many breeds and varieties. In many respects, therefore, the standard-bred poultry industry served as a foundation for the subsequent development of the industry. Poultry exhibitions have exercised a remarkable influence in maintaining high standards of excellence and in fostering the interests of the industry.

Relative Value of the Chicken.—The majority of the breeds possess egg-laying and meat-producing qualities, and many of them also possess beautiful combinations of color patterns which give chickens a very important place in animal breeding. Then, again, the relatively small size of chickens, as compared with cattle, sheep, and hogs, makes them particularly adaptable to a wide variety of conditions. These factors account in a large measure for the great number of breeds and varieties that exist and for the variation in type, color, and color patterns.

Numerous Breeds and Varieties.—The breeds and varieties of chickens are so numerous that a detailed discussion of all the characters they possess is not possible in this book. Moreover, the reader is referred to the "American Standard of Perfection," published by the American Poultry Association (1930), and to the other works listed at the end of this chapter.

The breeds are classified largely from the standpoint of their origin, emphasis being placed upon the more important characteristics of economic importance in the more popular breeds and upon the unusual characteristics of those breeds and varieties bred largely for pleasure.

It should be noted, however, that not all varieties belonging to the same breed necessarily have the same ancestry.

Significance of Type.—The distinguishing feature whereby one breed of fowls differs from another breed is in respect to type, although this is rather a confusing situation, inasmuch as the visible body type is influenced not only by the actual shape of the body but also by the feather

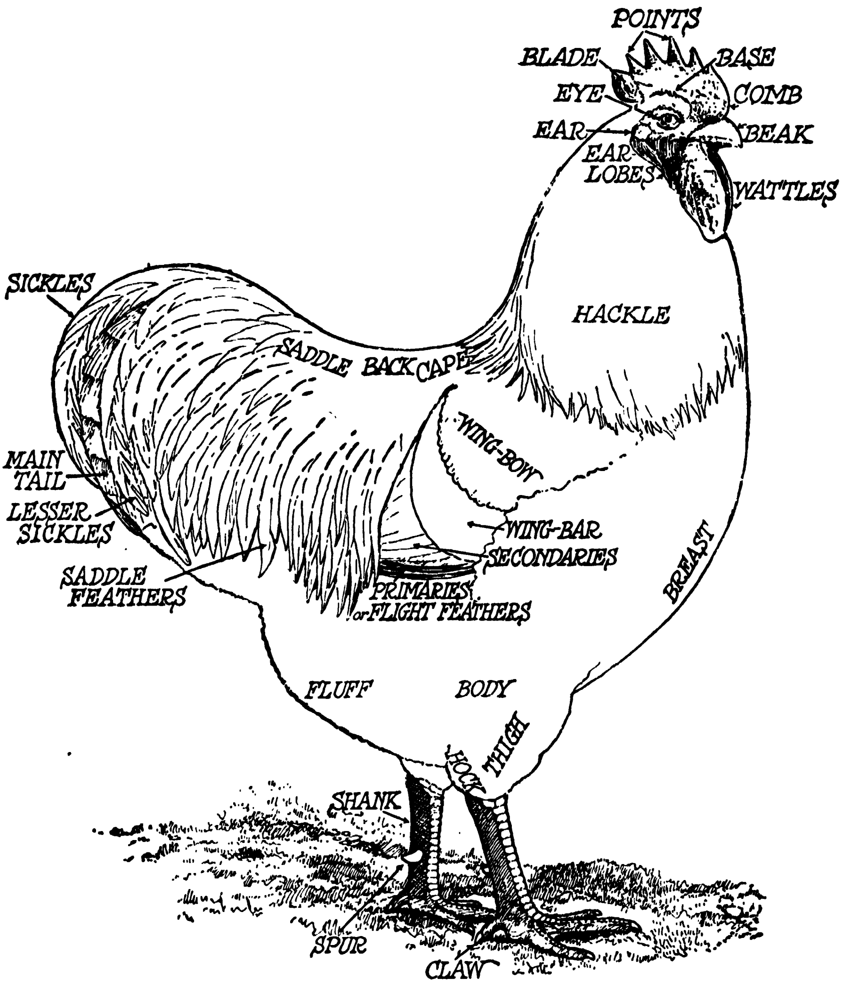


FIG. 2.—Glossary chart giving the names of the different parts of the male fowl. (*U. S. Dept. Agr.*)

contour. In breeding standard-bred poultry, the "type" of bird, as determined by feather contour, has been regarded as of greatest importance, so much so that in many cases the actual body type has received minor attention. The situation has developed so that it is now recognized that "shape makes the breed," shape here indicating very largely feather contour.

Variety Colors.—Within each breed of fowls there naturally was a tendency to segregate various color combinations, or, where only one color existed in the original breed, there was a tendency to develop new color patterns. In either case, it was necessary to adhere to the original type or shape characteristic of the breed, and thus it has arisen that varieties of a breed are supposed to be identical in all characteristics except plumage color or, in some cases, in respect to the shape of comb, standard weight, color of shanks, and other minor characteristics. There is a large grain of truth in the old saying of poultry breeders that "shape makes the breed and color the variety."

The illustrations in the accompanying pages are designed to present the standard type of various breeds and should be studied closely. The problem of an adequate color description for the numerous varieties is simplified materially, because there are relatively few standard color patterns. For instance, the color patterns of the Dark Brahma, Silver Penciled Plymouth Rock, and Silver Penciled Wyandotte are almost identical. So also in the case of the color patterns of the Light Brahma, Columbian Plymouth Rock, and Columbian Wyandotte. The plumage pattern and feather markings of the Partridge Cochin are identical with those of the Partridge Plymouth Rock and Partridge Wyandotte. There are black varieties and white ones of many breeds, and there are blue varieties of a few breeds, in each case the color being identical.

AMERICAN BREEDS

A number of breeds have been developed in America to meet the market demand for a bird with a yellow skin, clean shanks, and adapted to the conditions of the country. All birds belonging to the American class are spoken of as being "clean legged"; *i.e.*, they have shanks free from feathers. They also have yellow shanks and skin, except Java and Jersey Black Giant, which have yellow skins but black shanks. All have red ear lobes and, except the Lamona, lay brown-shelled eggs and are classed as broody.

Dominique.—From the best records available, it appears that purely barred chickens of relatively small size and usually with rose combs were common in many parts of the eastern United States as early as 1750. Interest in poultry breeding increased, and more attention was given to the improvement of these barred chickens until they came to possess a fair degree of uniformity in type and were more or less the same size. They were recognized under the breed name "Dominique," but their popularity soon waned.

In plumage color the Dominique has a generally bluish or slaty cast; the feathers in all sections are barred with alternate, rather irregular

light and dark bars. The markings lack the clean-cut effect of the Barred Plymouth Rock barring. The comb is rose. The standard weights, in pounds, are: cock, 7; hen, 5; cockerel, 6; pullet, 4.

Plymouth Rock.—The Plymouth Rock is one of the most popular breeds in America, largely because it is a bird of good size, with excellent fleshing properties and good egg-laying abilities. The birds belonging to this breed are rather long bodied, fairly broad, with fairly prominent breast and good depth of body. This breed has a single comb. The standard weights, in pounds, are: cock, 9½; hen, 7½; cockerel, 8; pullet, 6.

The Barred Plymouth Rock seems to have been developed from at least three fairly distinct strains. The Drake strain was originated about 1866 at Stoughton, Mass., the original stock probably being single-comb barred birds. The Sussex County strain was also developed in Massachusetts, going as far back as 1856. The Upham, or Spaulding-Upham, strain was developed in Connecticut about 1865 or 1866. Cochins and Dorkings were the two breeds used to a greater extent than any others, with the exception of the Dominique, which was frequently used as foundation stock in some of the original crosses as well as in some backcrosses. The barred plumage of the Barred Plymouth Rock was derived from the Dominique. As time went on, the three original strains were crossed to a considerable extent.

The plumage color is grayish white, each feather crossed by almost black bars which should be even in width, straight, and should extend down to the skin. Each feather should end with a narrow, dark tip, which with the alternate dark and light bars gives a bluish cast or shade to the surface color. The barring in the hackle and saddle of the male is narrower than in other sections. Solid black or partly black feathers may occur in some birds of practically all strains in this variety, but their appearance does not necessarily indicate impurity of breeding. Black spots on the shanks are also common, particularly in females, but they do not indicate impurity of breeding.

In the breeding of Barred Plymouth Rocks there is a decided tendency for the males to come lighter in color than the females, and for this reason the "Standard of Perfection" provides for certain standards pertaining to the width of barring in males and females. In the males the black and white bars should be of equal width, whereas in the females the white bars are one-half as wide as the black bars.

From the economic standpoint, there are decided disadvantages resulting from the breeding of Barred Plymouth Rocks that have very narrow barring. Strains bred for very narrow barring are frequently noted for slow growth, poor feathering in early life, and defects in the wings and tails of adult birds. A single mating system involving the

mating of males and females that have fairly good width of barring is in the best interests of the variety.

The White Plymouth Rock originated as a "sport" from the barred variety. It is quite possible, however, that other strains of White Plymouth Rocks were developed from crosses of White Dorkings and White Cochins, and it is also possible that White Dorkings were crossed with Barred Plymouth Rocks, and then the white color factor extracted from subsequent generations. The plumage color is pure white throughout and should be free from black ticking, brassiness, and creaminess.

The Buff Plymouth Rock was developed in an entirely different manner from the Barred variety and apparently has no relation to it. Two strains of Buff Plymouth Rocks were originated about 1890, one being developed from single-comb Rhode Island Reds which were common in Rhode Island at that time although not recognized under that name; the other strain was developed from crosses of White Plymouth Rocks and Buff Cochins. The plumage color is golden buff in all parts of the surface color, and all sections should be of the same shade. The presence of feathers having a shaft of different color from the rest of the feather and the presence of feathers sprinkled with lighter color are of common occurrence but are undesirable. The undercolor is of little lighter shade than the surface color.

The Silver Penciled Plymouth Rock owes its feather markings, to a considerable extent, to the Dark Brahma. It has a distinctive color pattern in which the male differs considerably from the female.

The plumage of the male consists of a silvery white surface color, extending over the wing bows and back, and the hackle and saddle are silvery white, striped with black. The rest of the plumage, including the main tail feathers and sickles, is black. The primaries are black, except for a narrow edging of white on the lower edges of the lower webs, and the secondaries are also black, with some white.

In the female the general surface color is gray, with a distinct, concentric penciling of dark gray on each feather. The neck feathers are silvery white, with a black center showing a slight gray penciling, and the main tail feathers are black, with the two top feathers showing some penciling. In both sexes the undercolor is slate, shading to a lighter color toward the base in the male.

The Partridge Plymouth Rock, developed apparently from Partridge Cochins and Brown Leghorns, in color pattern is practically the same as the Silver Penciled Plymouth Rock, except that the white in the Silver Penciled is replaced by red or reddish brown.

The hackle of the male is greenish black with a narrow edging of brilliant red; the plumage in front of the neck is black. The wing bow is brilliant red. The primaries are black, with the lower edges reddish

bay, and the secondaries are also black, the outside web of reddish bay with greenish black at the end of each feather. The back has brilliant red feathers, each with a greenish-black stripe down the middle.

In the female the neck is reddish bay, and the front of the neck and breast are both deep reddish bay, distinctly penciled with black. The wing bows are also deep bay penciled with black. The primaries are black with an edging of deep reddish bay on the outer webs, the inner webs of the secondaries are black, and the outer webs are reddish bay deeply penciled with black. The back is also deep reddish bay penciled with black. The undercolor of all sections of both sexes should be slate. The beak is dark horn shading to yellow at the tip.

The Columbian Plymouth Rock was developed from crosses between Light Brahmas and White Plymouth Rocks. Most of the plumage is white, although the hackle feathers of the male and the neck feathers of the female and the tail coverts of both sexes are black, with a distinct white lacing. The tail feathers in both sexes are black. The wings also carry some black on the primary and secondary feathers, which is almost hidden when the wings are folded. The undercolor of all sections in both sexes should be light bluish slate.

The Blue Plymouth Rock was first recognized as standard variety in 1919. In the male the plumage color over practically all parts is a medium shade of slaty blue, each feather laced with darker blue, and in the wing bows, hackle, back, saddle, sickle feathers, and tail coverts the lacing is very dark. This gives the surface color of the upper sections of the male a very dark appearance. In the female the general plumage color is a slaty blue of even shade, each feather except the primaries having a well-defined, narrow lacing of darker blue. The neck is decidedly darker than the rest of the body color. Both sexes have a slaty blue undercolor.

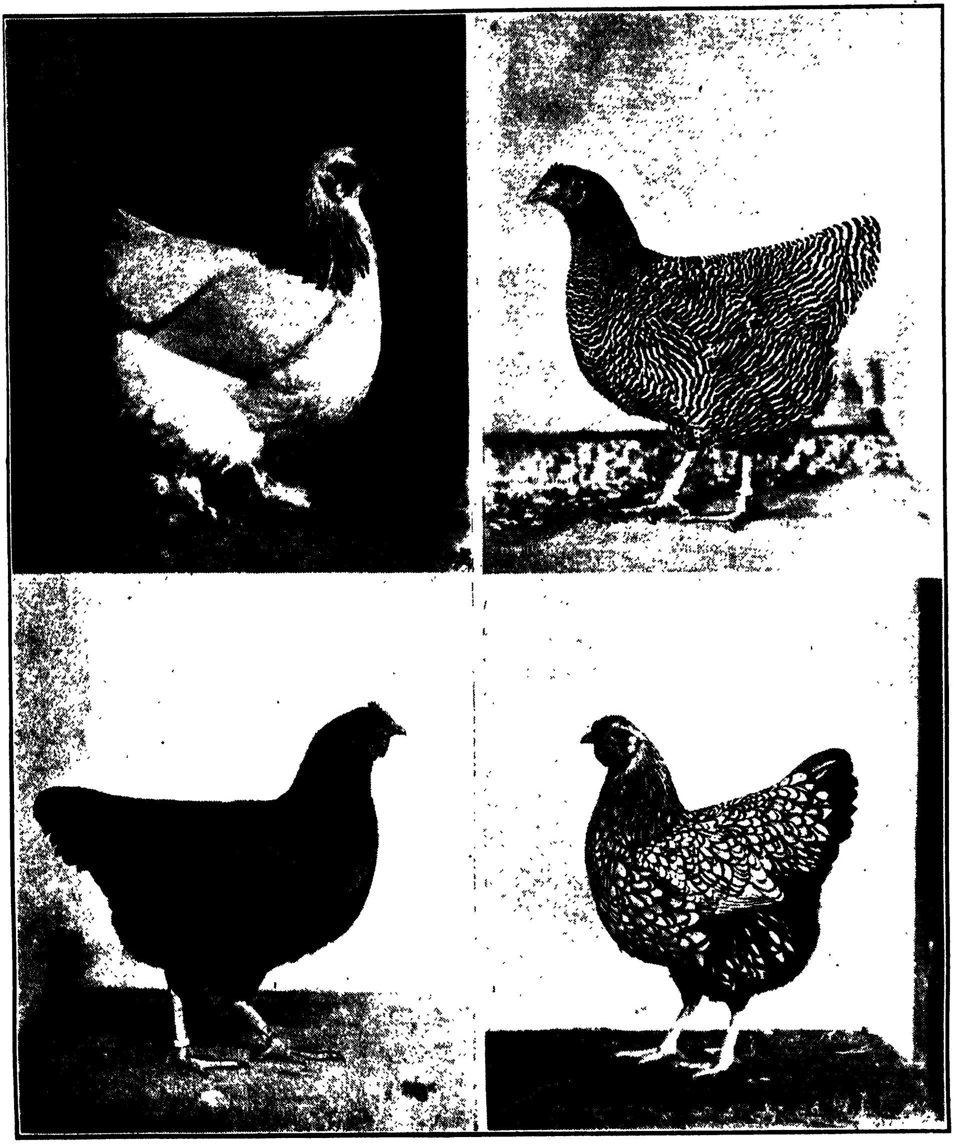
Wyandotte.—The body of the Wyandotte is comparatively round, and the general shape and character of feathering give it an appearance of having a rather short back and being low set. Like the Plymouth Rock, it is a good general-purpose breed, well adapted for flesh production and a good layer when bred for egg production.

All Wyandottes have rose combs. The standard weights, in pounds, are: cock, 8½; hen, 6½; cockerel, 7½; pullet, 5½.

The Silver Laced Wyandotte was the first variety developed, about 1860, principally from crosses between Buff Cochins and Silver Sebright Bantams and from crosses between Dark Brahmas and Silver Spangled Hamburgs. This variety has a striking color combination which makes it very attractive.

The male has a silvery white hackle, back and saddle, the hackle and saddle feathers being striped with black. The feathers of the body

and breast are white, laced with a black edge. The primaries are black with the lower edges white; the secondaries are also black with the lower



Light Brahma. Barred Plymouth Rock.
S. C. Rhode Island Red. Silver Laced Wyandotte.

Fig. 3.

half of the outer webs white and the upper webs edged with white. The main tail feathers are black.

The female has white feathers laced with black over the entire body, except the neck feathers, which are black; there is also some black in the wings. The primaries and secondaries are practically the same as in the

male. In both sexes the undercolor is slate, in the male shading to lighter slate at the base of the feathers.

The White Wyandotte originated as a sport of the Silver Laced variety and is white throughout and, like the White Plymouth Rock, should be free from any brassiness or creaminess or black ticking.

The Buff Wyandotte was developed about 1890 by mating Golden and White Wyandottes with Buff Cochins, from Hamburg and Cochin crosses and from fowls that were common in Rhode Island. The plumage color is an even shade of buff throughout, identical with that of the Buff Plymouth Rock.

The Golden Laced Wyandotte was developed from crosses in which the Silver Laced Wyandotte, the single- and rose-comb Brown Leghorn, and the Buff and Partridge Cochin were used. The Golden Laced Wyandotte has the same general color scheme as the Silver Laced variety, except that the white is replaced with red and reddish brown. The undercolor is slate, in the male shading to red at the base.

The Partridge Wyandotte originated between 1890 and 1896 from crosses between Golden Laced Wyandottes and Golden Penciled Hamburgs and from mixtures of Golden Laced Wyandottes, Cornish, Brown Leghorn, and Buff and Partridge Cochin. It has the same color pattern as the Partridge Plymouth Rock.

The Silver Penciled Wyandotte was developed from the Dark Brahma, with its penciling, and Silver Penciled Hamburgs and Partridge and Silver Laced Wyandottes. It has the same color pattern as the Silver Penciled Plymouth Rock.

The Columbian Wyandotte appears to have been developed from matings between Light Brahmas and other breeds. It has the same color pattern as the Columbian Plymouth Rock.

The Black Wyandotte appeared about 1885 as a black sport of the Silver Laced variety. It is black in all sections, showing a greenish sheen, free from purple barring. The undercolor is slate.

Rhode Island Red.—The Rhode Island Red has a rather long, rectangular body and appears somewhat more upstanding than the Plymouth Rock or the Wyandotte. At the same time, the body has good depth and is wide and of good length, making a good meat-producing bird. By proper breeding methods this breed can be developed into excellent layers. There are two varieties, single comb and rose comb, which are otherwise identical. The standard weights, in pounds, are: cock, 8½; hen, 6½; cockerel, 7½; pullet 5½.

This breed was developed in the first quarter of the nineteenth century from matings of Red Malay game cocks to the common hens of Rhode Island and from matings between rose-comb Brown Leghorns and mottled females.

The plumage color of the Rhode Island Red is a rich brownish red, which should be as even as possible over the entire surface and throughout all sections, except that the lower webs of the primaries are mostly black; the upper webs of the secondaries are partly black; and the tail coverts, sickle feathers, and main tail feathers are black. In the lower neck feathers of the female there is also a slight ticking of black. The undercolor of all sections in both sexes should be red and free from a dark or slaty appearance, which is known as "smut." The beak is reddish horn, and the shanks and toes are rich yellow or reddish horn.

Rhode Island White.—The Rhode Island White, of which the rose comb is the only variety, is identical in size and type with the rose-comb Rhode Island Red and was developed from White Wyandottes, Partridge Cochins, and rose-comb White Leghorns. The plumage should be pure white, free from any tint of brassiness.

New Hampshire.—The New Hampshire was developed from the Rhode Island Red, apparently with some crossing with one or more other breeds. In shape of body the New Hampshire is less rectangular than the Rhode Island Red. The plumage surface color is chestnut red, otherwise similar to Rhode Island Red plumage color. The comb is single. The standard weights, in pounds, are: cock, 8½; hen, 6½; cockerel, 7½; pullet, 5½.

Jersey Black Giant.—The Jersey Black Giant, developed largely from Asiatic sources, is the largest of the American breeds. It resembles the Plymouth Rock in type but is broader, deeper, and longer. The comb is single. The standard weights, in pounds, are: cock, 13; hen, 10; cockerel, 11; pullet, 8.

The plumage in all sections is black with a greenish sheen. The undercolor is slate, approaching white at the skin. The beak is black, shading to yellow toward the tip. The shanks are black with yellow on the undersurface of the feet and toes.

Java.—The Java includes two varieties, the Black and the Mottled, in the latter variety the black being more plentiful than the white. It is a bird of good size, having a long and deep body with good width of back and a full, well-rounded breast. The comb is single. The standard weights, in pounds, are: cock, 9½; hen, 7½; cockerel, 8; pullet, 6½.

Lamona.—The Lamona was developed from crossing the Silver Gray Dorking, White Plymouth Rock, and White Leghorn. It has white plumage, an oblong body, and lays a white egg. The standard weights, in pounds, are: cock, 8; hen, 6½; cockerel, 7; pullet, 5½.

Buckeye.—The Buckeye is an American product resulting from the infusion of blood from the Barred Plymouth Rock, Buff Cochin, Dark Cornish, and Black Breasted Red Game. The comb is pea shaped.

The standard weights, in pounds, are: cock, 9, hen, 6½; cockerel, 8; pullet, 5½.

The surface color of the Buckeye is mahogany bay, with a slightly darker shade on the wing bows of the males. The flight and main tail feathers of the male may contain black. The undercolor in both sexes is red, except in the back, where there is a bar of slate across each feather below the surface.

Chantecler.—The White Chantecler originated in Canada between 1908 and 1920 from crosses between Cornish, White Leghorn, White Wyandotte, White Plymouth Rock, and Rhode Island Red. It is pure white in all sections of its plumage. The most noticeable characteristics of the breed are a conformation resembling that of the Cornish, especially in breast development and carriage, the smallness of the cushion-shaped comb and the very small wattles. The standard weights, in pounds, are: cock, 8½; hen, 6½; cockerel, 7½; pullet, 5½.

The Partridge Chantecler has the same color of plumage as the Partridge Plymouth Rock. The standard weights, in pounds, are: cock, 10; hen, 7½; cockerel, 8½; pullet, 6½.

ASIATIC BREEDS

Of the three Asiatic breeds recognized as standard, the Brahma, Cochin, and Langshan, only the first two ever gained particular prominence in the American poultry industry. With the development of the American breeds, however, the popularity of the Asiatic breeds was not maintained, and they are now bred to a limited extent only.

The breeds belonging to the Asiatic class are of distinctive type and have large bodies, feathered shanks, and are usually heavy in bone. All have yellow skin, except the Black Langshan, whose skin is a pinkish white. All have red ear lobes, lay brown-shelled eggs, and are classed as broody.

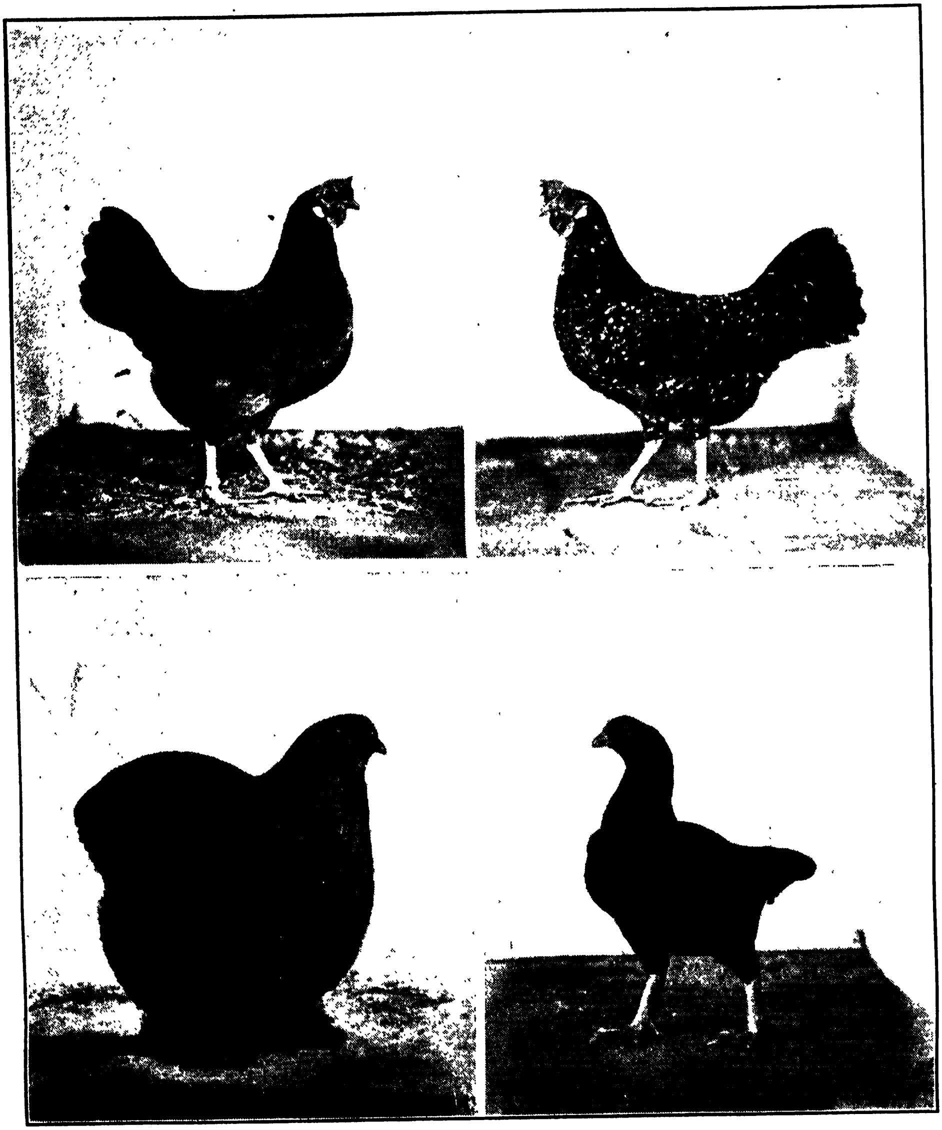
Brahma.—The earliest Brahmas originated in the Brahmaputra district of India, where fowls of the original type, known as "Gray Chittagongs," are still to be found. The Brahma apparently was first imported into America in September, 1846, and into England in 1853.

Brahmas are massive in appearance, well feathered, and well proportioned. One characteristic of this breed is its pea comb. The standard weights of the Light Brahma, in pounds, are: cock, 12; hen, 9½; cockerel, 10; pullet, 8; and of the Dark Brahma: cock, 11; hen, 8½; cockerel, 9; pullet, 7.

The Light Brahma has the same color pattern as the Columbian Plymouth Rock and Columbian Wyandotte.

The Dark Brahma has the color pattern of the Silver Penciled Plymouth Rock and the Silver Penciled Wyandotte.

The Buff Brahma has the same color pattern as the Columbian Plymouth Rock except that golden buff or buff replaces white, and in the



S. C. Light Brown Leghorn. S. C. Ancona.
Partridge Cochin. Dark Cornish.

Fig. 4.

Buff Brahma the shank feathers are buff and the feathers on the outer toe of each foot are buff and black, the black being laced with buff.

Cochin.—The Cochin originated in the Shanghai district of China and was known as the "Shanghai fowl." It was first imported into England in 1845 and a little later into America. The outstanding char-

acteristics of the Cochin are its massive appearance and abundantly feathered shanks. The breast of the Cochin is carried low, and in the female there is a very prominent development of the cushion at the base of the tail. The feathering is extremely long and profuse so that the Cochin appears much larger than is really the case. All Cochins have single combs. The standard weights, in pounds, are: cock, 11; hen, 8½; cockerel, 9, pullet, 7.

The Buff Cochin has the same even shade of golden buff as in Buff Plymouth Rocks and Wyandottes.

The White Cochin in color is like other white varieties, for a description of which see the White Plymouth Rock.

The Black Cochin is the same in color as the Black Wyandotte.

The Partridge Cochin is a parti-colored variety in which the sexes differ materially in feather markings, which are the same as in the Partridge Plymouth Rock and Partridge Wyandotte.

Langshan.—The Langshan originated in the Langshan district north of the Yangtze Kiang river in China. Langshans were imported into England in 1872 and a little later introduced into America. The principal characteristics of the Langshan as compared with the Brahma and Cochin are that the body is shorter but deeper, there is greater length of leg, the tail feathers are longer, and the tail is carried higher. The Langshan stands up well and is well proportioned, which makes it a very graceful bird. The comb is single. The standard weights, in pounds, are: cock, 9½; hen, 7½; cockerel, 8; pullet, 6½.

The Black Langshan has the same color qualifications as the Black Wyandotte except that the beak is dark brown, the shanks and toes are bluish black, and the bottoms of the feet are pinkish white.

The White Langshan is the same in color as the White Plymouth Rock except that the beak is light slate blue shading to pinkish white, and the shanks and toes are slaty blue, with pink between the scales.

ENGLISH BREEDS

The breeds of English origin described in the "American Standard of Perfection" are for the most part utility breeds noted for their excellent fleshing properties. With the exception of the Cornish, all the breeds have white skin and red ear lobes and, except the Dorking and Red Cap, lay brown-shelled eggs. All are classed as broody.

Orpington.—The Orpingtons are characterized by their size and shape of body, which is long, deep, and well rounded, with a full breast and a broad back. They are rather low set and heavy in bone. They are a little more loosely feathered than breeds of the American class. The Orpingtons make good table birds, and good laying strains have been developed when bred with that object in view. The comb is single.

The standard weights, in pounds, are: cock, 10; hen, 8; cockerel, 8½; pullet, 7.

The Black Orpington was produced about 1886 from matings involving the Black Minorca, clean-legged Black Langshans, and black colored specimens with Plymouth Rock blood. For a description of the color plumage see the Black Wyandotte. The shanks and toes are black, and the bottoms of the feet are white.

The Buff Orpington was evolved from Bluff Cochins, Dark Dorkings, and Golden-Spangled Hamburgs. The plumage color is the same as in other buff breeds, such as the Buff Plymouth Rock. The shanks and toes are white.

The White Orpington in all probability originated as a sport from the Black variety. The color is the same as in the White Plymouth Rock except that the shanks and toes are white.

The Blue Orpington, originated quite recently, has the same general color as the Blue Plymouth Rock except that the shanks and toes are leaden blue.

Cornish.—The Cornish, originally known as the Cornish Indian Game, appears to have been developed in England about the middle of the last century and was produced from crossings involving the Aseel, Malay, and English Game breeds. It was imported into America in 1887 and gained popularity partly because of its excellent fleshing properties and its yellow skin.

The Cornish is noted for its close feathering and compact, heavily meated body, which has a distinctive shape. The breast of the Cornish is very deep and broad, giving the shoulders great width. All Cornish birds have pea combs. The standard weights, in pounds, of the dark and white varieties, are: cock, 10; hen, 7½; cockerel, 8; pullet, 6; and of the white-laced red variety they are: cock, 8; hen, 6; cockerel, 7; pullet, 5.

The Dark Cornish male has greenish-black hackle and wing bows; the primaries are black except for a narrow edging of bay on the outer edge; the secondaries have the upper webs black and the lower webs black and bay; the back should be lustrous greenish black and dark red intermixed. The tail, lower part of the body, and fluff are black, and the breast is greenish black. In the female the neck is a lustrous black, each feather having a bay shaft; the wing bows are bay. The primaries are almost entirely black; the secondaries have the upper webs black; and the lower webs are black except that there is a broad margin of bay penciling. The back is bay color. The main tail feathers are black except the upper two, which are penciled with bay. The lower part of the body, fluff, and breast are bay with the feathers for the most part penciled. The undercolor of both sexes is dark slate. The beak, shanks, and toes are yellow.

The White Cornish was developed in America and is pure white in plumage color, and the beak, shanks, and toes are yellow.

The White Laced Red Cornish was also developed in America quite recently. The plumage color is quite interesting. It has, in both sexes, bright, rich-red neck feathers, in the male laced with silvery white and in the female with white. In both sexes the back, lower part of body, fluff, and breast are rich red in appearance, each feather regularly laced with a narrow lacing of white. In the male the tail is white; in the female the tail is red, except that the end of each feather is laced with white. The undercolor of all sections in both sexes is white.

Sussex.—The Sussex and the Dorking, described next, are two breeds developed in England about 200 years ago primarily as table birds. In the early history of these two breeds the Sussex were developed from birds with four toes, while the Dorkings were developed from birds of the same origin but with five toes.

The Sussex has a long body, broad at the shoulders and with good depth from front to rear. The breast is well developed, and the bird has excellent fleshing qualities. Fowls of this breed have single combs and horn-colored beaks, shanks, and toes. The standard weights, in pounds, are: cock, 9; hen, 7; cockerel, 7½; pullet, 6.

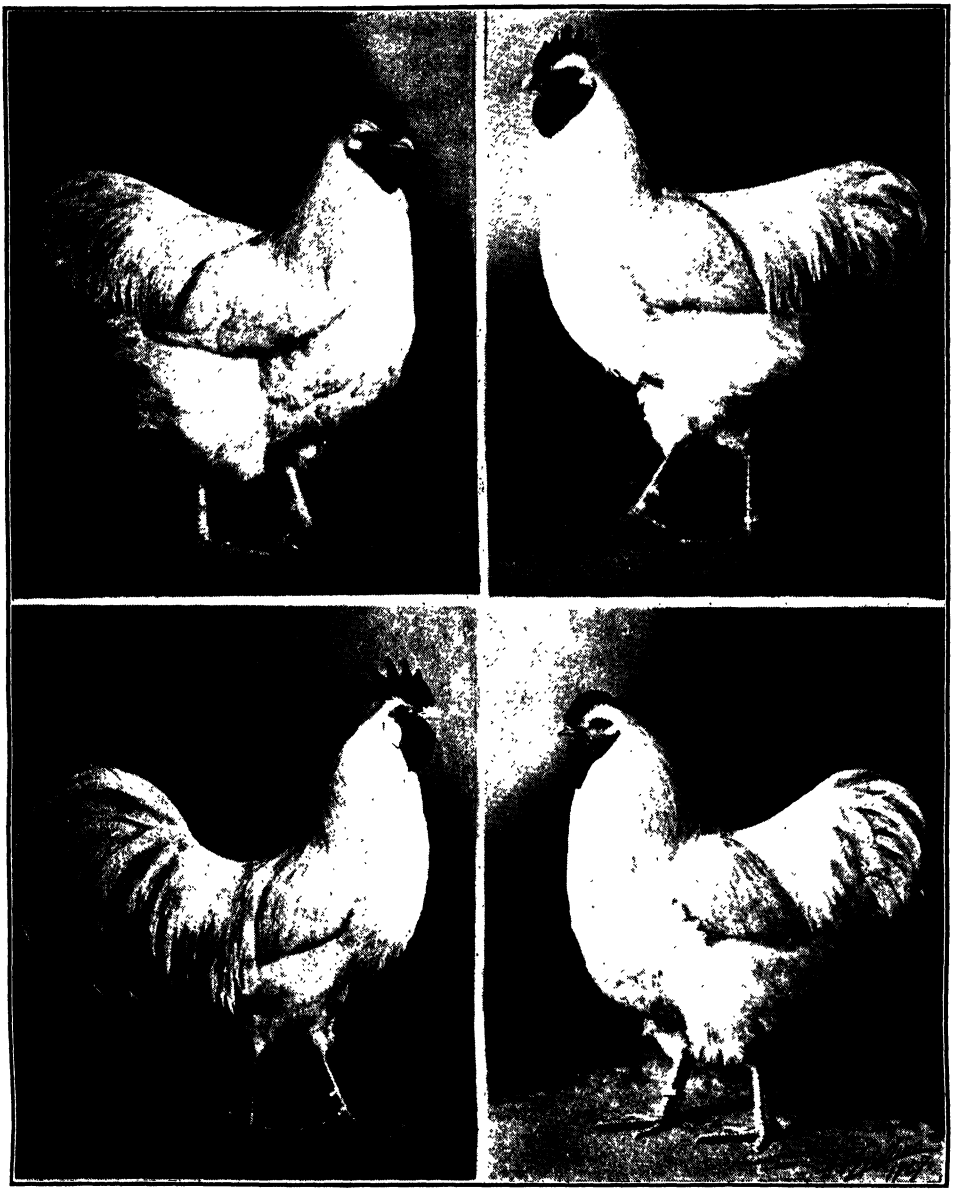
The Speckled Sussex is reddish bay in color, each feather tipped with white. In the male the neck is a lustrous, reddish bay, each feather having a black stripe extending lengthwise. The wing bows also are reddish bay; the primaries are black and white; the secondaries have the outer webs bay edged with white, and the inner webs are black edged with white. The back and saddle are reddish bay; the main tail feathers are black and white; the lower part of body, fluff, and breast are all reddish bay in color, each feather tipped with white. The female is for the most part reddish bay throughout except that the primaries and secondaries are the same as in the male. The undercolor of all sections in both sexes is slate shading to salmon.

The Red Sussex is a deep, rich red in both sexes. The only exceptions to the red color are found principally in the primaries, where the lower webs are black with a narrow edging of red, in the secondaries where the upper webs are black, and the tail, which is black. The undercolor of all sections in both sexes is red with a slight bar of slate.

The Light Sussex was first admitted to the "Standard of Perfection" in 1929. The color of the plumage is quite similar to the Columbian Plymouth Rock and Columbian Wyandotte.

Dorking.—The Dorkings, like the Sussex, are characterized by long, broad, deep, and low-set bodies. The White Dorking has a rose comb, whereas the other two varieties have single combs. All Dorkings have five toes. The standard weights, in pounds, of the White Dorking are:

cock, $7\frac{1}{2}$; hen, 6; cockerel, $6\frac{1}{2}$; pullet, 5; of the Silver-gray and Colored Dorkings, they are: cock, 9; hen, 7; cockerel, 8; pullet, 6.



White Orpington. White Plymouth Rock.
S. C. White Leghorn. White Wyandotte.

FIG. 5.

The White Dorking is white throughout and should be free from any foreign color, as in other white-colored breeds. The beak, shanks, and toes are white.

The Silver Gray Dorking is a parti-colored bird in which the sexes differ in feather markings.

The male has a white hackle, and the plumage on the front of the neck is black. The wing bows are silvery white; the primaries have the upper webs black and the lower webs white; the secondaries are the same as the primaries except that in the secondaries there is a black spot in each feather. The back and saddle are silvery white, the tail is black, and the sickles and coverts are greenish black; the lower part of the body and the fluff are also black.

In the female the neck is silvery gray, each feather having a black stripe extending down its center. The wing bows are silvery white; the primaries have the upper webs dark slate and the lower webs gray; The secondaries are the same as the primaries. The back is grayish white, and the tail is black. The undercolor of all sections in both sexes is slate. The beak is white streaked with horn, and the shanks and toes are white.

The Colored Dorking is also parti-colored, with sex differences in feather markings.

The male has a light-straw-colored hackle; the wing bows are a light-straw color; the primaries are black or dark slate; the secondaries have the upper webs black and the lower webs white. The saddle feathers are also light-straw color with a black stripe down the middle of each feather. The breast, lower part of body, fluff, and tail are black.

In the female the neck is black with gray edging on the front of each feather; the wing bows are black; the primaries are slaty brown; the secondaries have the upper webs black and the lower webs black with a mixture of dark red. The back of the female is lustrous black; the tail is dark brown; the lower part of the body is black slightly mixed with gray, and the fluff is dull black edged with gray. The undercolor of all sections in both male and female is slate. The beak is dark horn, and the shanks and toes are white.

Red Cap.—The Red Cap is supposed to have been developed from Old English Games and Golden Spangled Hamburgs. The name "Red Cap" is derived from the large rose comb. It is a bird of medium size with a fairly long body and a rather prominent breast. A large, rose comb is characteristic of the breed. The standard weights, in pounds, are: cock, 7½; hen, 6; cockerel, 6; pullet, 5.

Australorp.—The Australorp is a breed admitted to the "Standard of Perfection" in 1929. As the name suggests, it was developed in Australia from the Black Orpington. It is more upstanding and less massive in appearance than the Black Orpington and has been developed as an egg producer. The back is rather long, with a gradual sweep to the tail, and the body is of good depth, but the feathering fits more closely to the

body than in the Orpington. The comb is single, the beak is black, and the shanks and toes are black or leaden black with the bottoms of the feet and toes pinkish white. The plumage color is lustrous greenish black in all sections, and the undercolor is dull black. The standard weights in pounds, are: cock, 8½; hen, 6½; cockerel, 7½; pullet, 5½.

MEDITERRANEAN BREEDS

The breeds of Italian origin are smaller than the Asiatic and other classes, and in America the Leghorns especially have been bred for egg production rather than for the production of table poultry, except as broilers. The breeds of Spanish origin are somewhat larger than the Leghorns and Anconas but have not been bred so extensively for egg production. All of the Mediterranean breeds have nonfeathered shanks, white or creamy-white ear lobes, lay white-shelled eggs, and are nonbroody.

Leghorn.—The Leghorn originated in Italy and was first imported into America about 1835 and from America was imported into England. The breed is noted for the graceful blending of its different sections and its stylish carriage. All of the varieties of Leghorns have yellow beaks, skin, shanks, and toes. The standard weights, in pounds, are: cock, 6; hen, 4½; cockerel, 5; pullet, 4. There are single-comb and rose-comb varieties.

The single comb in the male should be of medium size and should stand erect, with five regular, deeply serrated points, the back of the comb extending straight out from the back of the head. In the female the front of the first point should stand erect, but the remainder of the comb should droop to one side. The comb in both sexes should be free from wrinkles, "thumbmarks," or folds.

In the rose-comb variety the comb of the male should be of medium size and square in front, well filled and free from hollows, the spike well developed and extending straight back from the head. In the female the comb is small and neat and in shape is like that of the male.

The Single-comb White Leghorn is white throughout and should be free from any brassiness or creaminess, as in other white varieties.

The Rose-comb White Leghorn is identical with the Single-comb White Leghorn, except for the rose comb.

The Single-comb Light Brown Leghorn was first imported into America about 1835. It is parti-colored, the female being more somber colored than the male. The latter has a hackle of orange color, the lower feathers of which are striped down the middle with black. The breast is black, the wing bows are bright red, the back is reddish brown, and the saddle is light orange or lemon; the feathers of the back and saddle should be free from shafting. The dull-black primaries and secondaries have the lower webs edged with brown. The feathers over the lower part of the body are slate tinged with brown. The tail is black.

In the female the neck feathers are golden yellow with a black stripe extending down the center of each feather. The breast is a rich salmon color and should be free from penciling, stippling, or shafting. The sides of the breast shade gradually to the color of the wings. The primaries are a slaty brown with the outer webs showing a narrow edging of brown. The secondaries are brown, with the outer webs finely stippled with lighter brown. The back, body, tail coverts, wing bows, and coverts in surface color are of light brown, finely stippled with darker brown. The shade of color over the back, wing bows, and coverts should be even, and the feathers free from shafting. The fluff and thighs are slate, tinged with brown. The undercolor in both sexes is slate.

The Single-comb Dark Brown Leghorn male has a dark-red head, a rich-red hackle and saddle, and the feathers are striped with a greenish-black stripe extending through the middle of each feather. The back is of the same shade as the hackle but is without striping. The wing bows are rich red, the fronts and coverts greenish black, which show as a distinct wing bar when the wing is folded. The primaries are black, the lower webs edged with brown. The secondaries are black, the lower webs showing edges of brown. The tail, body, breast, fluff, and thighs are black. The undercolor throughout is slate.

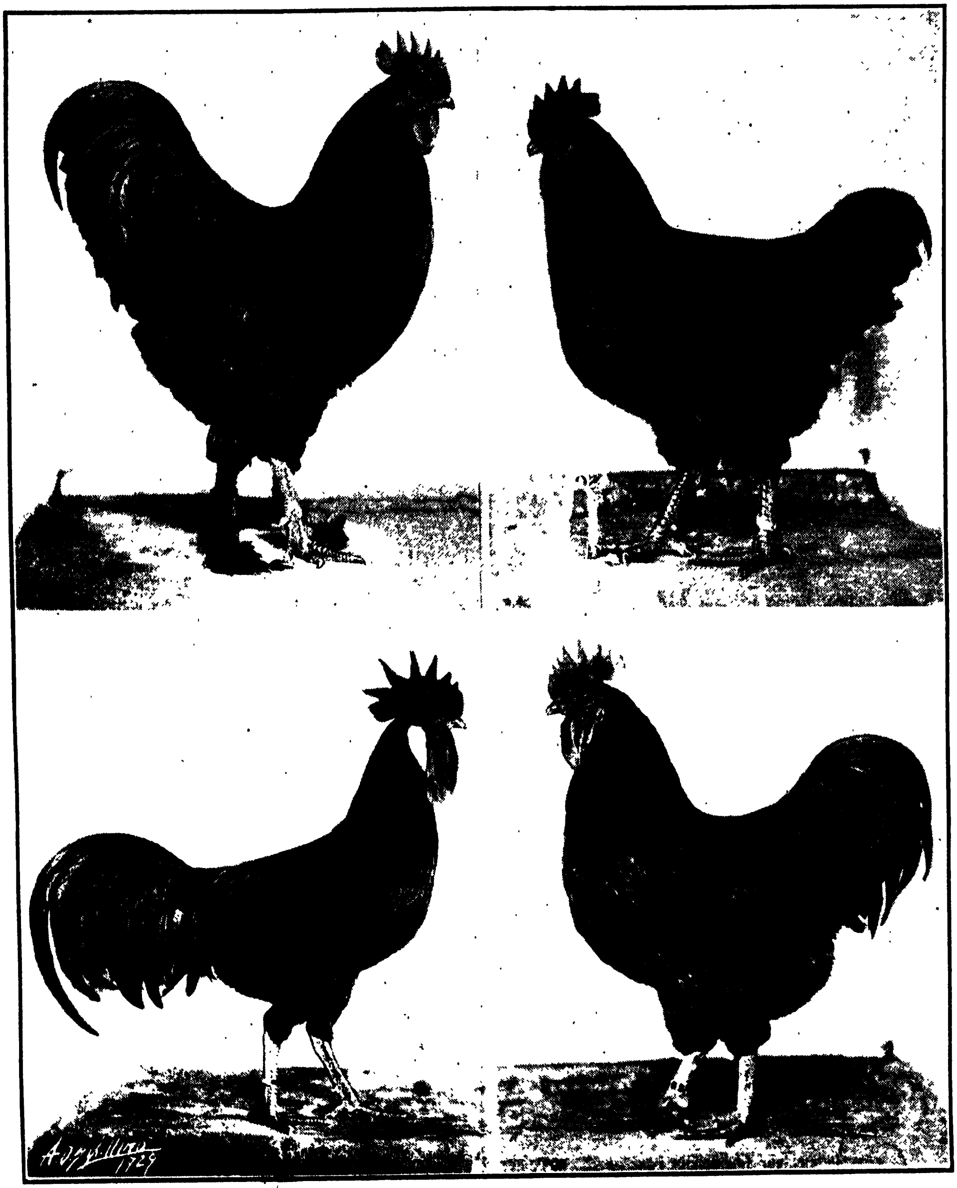
The female is of a darker shade than the female of the Light Brown variety. The neck feathers should be well striped with black. The breast is a dark reddish salmon stippled with brown. The wings and back should be black, stippled with a darker brown. There should be no shafting, but the plumage should show a greenish sheen free from purple. The stippling is much coarser than in the Light Brown female. The undercolor should be slate, running quite dark down to the skin.

The Rose-comb Brown Leghorn was produced about 1880 from crosses between the Red Cap and the Golden Spangled and Golden Penciled Hamburgs. Originally in the color pattern the male was the counterpart of the male of the Single-comb, Dark Brown variety, and the female in color pattern the counterpart of the Single-comb, Light Brown variety. In the "Standard of Perfection" now, however, the Rose-comb Brown Leghorns are divided into two classes, as in the case of the Single-comb variety, light brown and dark brown. The Rose-comb Dark Brown Leghorn male and female are color counterparts of the Single-comb Dark Brown Leghorn male and female, respectively. The same thing applies to the color of the Rose-comb Light Brown Leghorn male and female when compared with the Single-comb Light Brown Leghorn male and female, respectively.

The Single-comb Buff Leghorn is of the same golden-buff color as found in the Buff Plymouth Rock and other buff varieties.

The Rose-comb Buff Leghorn is the counterpart in color of the Single-comb Buff variety.

The Single-comb Black Leghorn should be black in all sections, showing a lustrous sheen free from purple barring. The undercolor throughout is dull black.



Black Langshan. Jersey Black Giant.
S. C. Black Minorca. Australorp.

Fig. 6.

The Silver Leghorn is of relatively recent origin in which the sexes differ materially in feather markings.

The male has a silvery white surface color; the head is silvery white, and the hackle is white, each feather having a median stripe of black. The wing fronts and shoulders are black, the bows are silvery white, the coverts black, forming a distinct bar across the wing. The primaries are black, except for the silvery white outer edges of the lower feathers. The secondaries are also black; the back, saddle, and lower tail coverts are silvery white. The cape, main tail feathers, sickles, upper tail coverts, breast, body, thighs, and fluff are black.

In the female the head and neck are silvery gray, each feather of the latter showing a narrow black stripe. The wing bows and coverts are silvery white, finely stippled with ashy gray, giving these sections a general gray cast. In the primary and secondary feathers the upper webs are gray, and the lower webs slaty gray. The front of the neck is a light salmon, and the breast is salmon, fading gradually to the color of the wings at the side. The back, body, and thighs are the same color as the wing bows and coverts. The tail is black, except that the upper two feathers are light gray and the tail coverts are gray. The fluff is a light, ashy gray. In both sexes the undercolor is gray throughout.

The Red Leghorn is a newly developed variety of Leghorns, having been admitted to the "Standard of Perfection" in 1929. The color of the surface plumage is an even shade of rich brilliant red, and the undercolor is red.

The Black Tailed Red Leghorn is also another newly developed variety of Leghorns admitted to the "Standard of Perfection" in 1929. The plumage color is practically identical with that of the Rhode Island Red.

The Columbian Leghorn was first admitted to the "Standard of Perfection" in 1929. The plumage color is similar to that of the Columbian Plymouth Rock and Columbian Wyandotte.

Ancona.—The Ancona originated in the vicinity of Ancona in Italy. It was imported into England about the middle of the last century, and from England it was later imported into America. It is of the same general type as the Leghorn. The standard weights, in pounds, are: cock, 6; hen, $4\frac{1}{2}$; cockerel, 5; pullet, 4.

The Single-comb Ancona and the *Rose-comb Ancona* are the two varieties of this breed, and they are identical in every respect except in the shape of the comb. The single comb is identical in shape with the Leghorn single comb of each sex, and the rose comb in the Ancona female is identical in shape with the Leghorn female rose comb; but in the Ancona male it is slightly smaller than in the Leghorn male.

The Ancona has a plumage color of lustrous black with certain of the feathers tipped with a V-shaped white tip. The proportion of feathers carrying such a white tip varies from one in two to one in five in different sections. The black surface color of the male has a greenish

sheen, which is absent in the female. The main tail feathers and sickles of the male and the main tail feathers of the female are each tipped with white. The primary and secondary wing feathers also carry white tips. The undercolor is dark slate throughout. The beak is yellow with the upper mandible shaded with black, and the shanks and toes are yellow or yellow mottled with black.

Minorca.—The Minorca either descended directly from the old Spanish Castilian breed or had the same common ancestor, but the more improved Minorcas came from the Balearic Islands off the east coast of Spain. It is noted for its length of body, large comb, and long wattles and is the largest of the Mediterranean breeds. The long back has a noticeable slope downward from the shoulders to the base of the tail. The tail is carried rather low and is well spread. The breast is prominent and well rounded. The skin of all varieties of the Minorcas is white.

In the single-comb varieties the comb is unusually large. In the male it is erect and has six evenly and deeply serrated points. The blade of the comb has a tendency to follow the neck. In the female also the comb is large and six-pointed, and the front of the comb folds to one side, the remainder drooping to the other side of the head.

In the rose-comb varieties the comb of the male is fairly large, square in front, and terminates in a well-defined spike which has a tendency to follow the neck. The rose comb of the female is practically the same in shape as that of the male but is smaller.

The standard weights in pounds of the Single-comb Black Minorcas are: cock, 9; hen, $7\frac{1}{2}$; cockerel, $7\frac{1}{2}$; pullet, $6\frac{1}{2}$. Of the other varieties of Minorcas the weights are: cock, 8; hen, $6\frac{1}{2}$; cockerel, $6\frac{1}{2}$; pullet, $5\frac{1}{2}$.

The Single-comb Black Minorca is black with lustrous, greenish sheen over the surface, which should be free from purple barring. The undercolor is dull black. The beak is black, and the shanks and toes are black or dark slate.

The Rose-comb Black Minorca is identical with the Single-comb Black Minorca in color, but is 1 pound lighter in standard weight.

The Single-comb White Minorca should be white throughout, free from any foreign color. The beak, shanks, and toes are pinkish white.

The Rose-comb White Minorca is the counterpart of the Single-comb White Minorca, except for the comb.

The Single-comb Buff Minorca should be an even, rich, golden buff throughout, as in the case of all buff varieties. The beak is light horn, and the shanks and toes are white or pinkish white.

White Faced Black Spanish.—*The White Faced Black Spanish* has a very extensive white face which should be quite smooth and free from wrinkles. In type the Spanish is very much the same as the Minorca, although it has not quite so long a body and has a somewhat higher

carriage of tail. The skin is white. The comb is single and rather large, although not so large as in the single-comb Minorca. It has five regular, deeply serrated points, and the blade extends nearly straight back from the head, having little, if any, tendency to follow the neck. The comb of the female is erect in front and droops to one side. The standard weights, in pounds, are: cock, 8; hen, 6½; cockerel, 6½; pullet, 5½. The plumage color should be black throughout with a lustrous, greenish sheen. The undercolor is dark slate throughout. The beak is black, and the shanks and toes are dark leaden blue or black.

Blue Andalusian.—The Blue Andalusian is of Spanish origin and is of interest mainly because of its interesting color, which is identical with that of the Blue Plymouth Rock, except that the skin is white, the beak horn colored, and the shanks and toes leaden blue. The comb is single, that of the male somewhat larger than the comb of the Leghorn, and the blade has a slight tendency to follow the neck. The comb of the female is practically identical with that of the Leghorn female. The standard weights, in pounds, are: cock, 7; hen, 5½; cockerel, 6; pullet, 4½.

CONTINENTAL EUROPEAN BREEDS

A number of breeds of Continental European origin are recognized as standard breeds in the "American Standard of Perfection." Very few of them, however, have gained great popularity, nor have they become of considerable economic significance, and because of these reasons they will be mentioned only briefly. For a more complete description of the Continental European breeds and varieties the reader is advised to consult the "American Standard of Perfection," published by the American Poultry Association, and for further information concerning breeds not included in the "American Standard of Perfection" some of the references given at the end of the chapter may be consulted.

The Houdan is a French breed and, like the Dorking, is five toed. The Houdan gained considerable prominence in France because of its laying and meat-producing qualities. In America, however, it does not hold a very prominent place in the industry. It has a well-developed crest, a beard, and a V-shaped comb. There are two varieties, the *Mottled* and the *White*. The standard weights, in pounds, are: cock, 7½; hen, 6½; cockerel, 6½; pullet, 5½.

The Faverolles originated in France from crosses involving the Houdan, Light Brahma, and possibly other breeds. In France it has proved to be a good table bird but has not gained prominence elsewhere. It has a beard, muffs, and feathered shanks. The *Salmon* is the only standard variety recognized in America, although in France there are also the *Light* and the *Black*. The standard weights, in pounds, are: cock, 8; hen, 6½; cockerel, 7; pullet, 5½.

The Crevecoeur is primarily a Normandy and Picardy breed, descended from the Black Polish. In America the *Black* is the only variety recognized as a standard breed, while France recognizes two others, *White* and *Buff*. The standard weights, in pounds, are: cock, 8; hen, 7; cockerel, 7; pullet, 6.

The La Flèche is another breed of French origin and, like the Crevecoeur, is not very popular in the United States. The general type is somewhat like the Crevecoeur; the plumage color is also solid black. On the other hand, the La Flèche has no crest or beard but has a V-shaped comb which is larger than that of either the Houdan or the Crevecoeur. The standard weights, in pounds, are: cock, 8½; hen, 7½; cockerel, 7½; and pullet, 6½. The La Flèche lays a white-shelled egg.

The Campine breed takes its name from the Campine district of Belgium where it was developed several centuries ago. Two varieties are recognized in America, the *Silver* and the *Golden*, the males in both varieties being hen feathered. The secondary sexual feathers, the hackle, saddle, and lesser tail feathers of the male are of the same shape and approximately the same length as in the female. The standard weights, in pounds, are: cock, 6; hen, 4; cockerel, 5; pullet, 3½.

The Buttercup was imported into America direct from Sicily in 1835. The characteristic feature of the Buttercup breed is the cup-shaped comb. The ear lobe is white. The standard weights, in pounds, are: cock, 6; hen, 4; cockerel, 5; and pullet, 3.

The Polish, according to the best information available, is descended from an old Italian breed, and early strains had infusions of other breeds. The outstanding characteristic of the Polish is a well-developed crest surmounting the head, and in some varieties there is also a beard. There are no standard weights. Outside certain sections of Europe the Polish is recognized largely as a fancy fowl. It was imported into America about 1835, and eight varieties are recognized as standard: the *White Crested Black*, the *Bearded* and the *Nonbearded Golden*, the *Bearded* and the *Nonbearded Silver*, the *Bearded* and the *Nonbearded White*, and the *Buff Laced*.

The Hamburg is probably the original rose-comb fowl, and its ancestry dates back to the time of the early poultry culture in Holland and Germany. The Hamburg is small in size, though there are no standard weights. The comb is rose, the spike of which turns slightly upward. The ear lobe is white. In America six varieties are recognized, the *White*, *Black*, *Golden Spangled*, *Silver Spangled*, *Golden Penciled*, and *Silver Penciled*.

The Malay is a black-red breed which apparently originated in southeastern Asia. The standard weights, in pounds, are: cock, 9; hen, 7; cockerel, 7; pullet, 5.

The Sumatra, a black breed, originated in the islands of the Asiatic Archipelago, including Sumatra. It has a very long, drooping tail and a V-shaped comb. There are no standard weights.

GAME BREED

The Game breed includes a number of varieties, but as a group it has certain definite characteristics. The birds are very striking in appearance, with solidly developed bodies with close-fitting plumage. They stand upright and have great width of the shoulders, with sloping backs and drooping tails. This general appearance is highly prized in the breed and is referred to in the "Standard of Perfection" as the "station" of the bird. A high-stationed bird is desired. The comb is single, although if dubbed (cut off) it should have a neat and smooth appearance; the comb and wattles of the cock bird should be dubbed. Games lay brown-shelled eggs and are classed as a broody breed.

The varieties of the Game class include the *Black Breasted Red, Brown Red, Golden Duckwing, Silver Duckwing, Birchen, Red Pyle, White,* and *Black.*

MISCELLANEOUS BREEDS

Three miscellaneous breeds recognized as standard in America include the **Frizzle,** with its peculiar development of the feathers which show a tendency to curve outward at their ends; the **Silkie,** with its blue skin and silky-appearing feather formation; and the **Sultan,** with its V-shaped comb, a crest, muffs, beard, and vulture hocks.

Of the many other miscellaneous breeds in the world today, only three will be mentioned, because of their peculiar characteristics. The **Yokohama,** of Japanese origin, is interesting from the fact that some of the tail and saddle feathers are developed to extreme length, sometimes as long as 20 ft. The **Araucana,** of South American origin, is of interest because it has a peculiar growth of feathers on each side of the neck, is frequently rumpless, and lays a light blue tinted egg. The **Creeper** is noted for its extremely short legs.

BANTAM BREEDS

Bantams are kept by many to whom the type appeals and who take pleasure in working out the breeding problem that it presents. The development of various color patterns is also an incentive in bantam breeding.

The breeds of bantams include miniatures of the varieties of Games, mentioned previously, and a number of ornamental breeds, including the *Golden* and the *Silver Sebright;* the *White* and the *Black Rose-comb; Wyandotte; Dark Cornish;* the *Light* and the *Dark Brahma;* the *Buff,* the

Black, the *White*, and the *Partridge Cochin;* the *Black*, the *Gray*, the *White*, and the *Black Tailed Japanese;* the *Booted White;* and *Mille Fleur Booted Bantam.*

JUDGING CHICKENS FOR STANDARD QUALITIES

Descriptions have been given of the ideal bird in most of the standard breeds and varieties recognized by the American Poultry Association, and it was pointed out that the majority of the breeds possess egg-laying and meat-producing qualities. Although it is true that every poultry breeder desires birds of the ideal breed type and variety color or other quality called for in the "Standard of Perfection," it is obvious that very

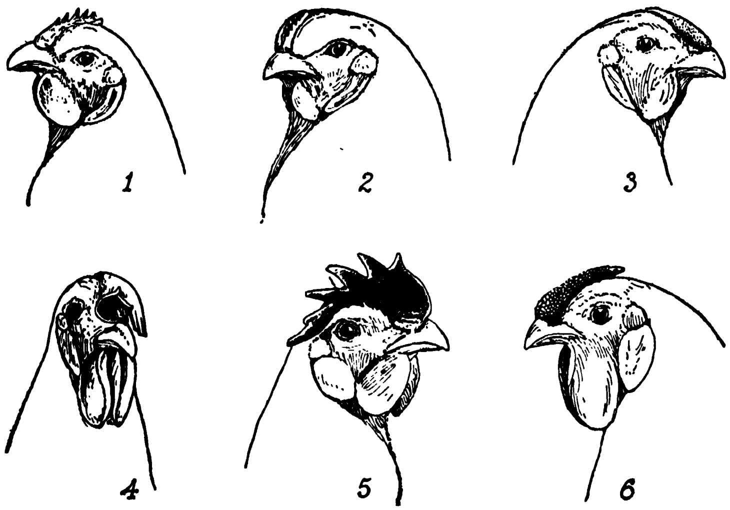


FIG. 7.—Types of combs on females of different breeds. 1, single (Plymouth Rocks and Rhode Island Reds); 2, pea (Brahmas); 3, rose (Wyandottes); 4, single (Minorcas); 5, single (Leghorns); 6, rose (Rhode Island Reds). (*U. S. Dept. Agr.*)

few birds attain the ideal. Hence, it is natural that poultry breeders should judge their fowls from the standpoint of the extent to which they approach the ideal.

As long as the public takes cognizance of the standard requirements of breeds and varieties, it seems obvious that some consideration should be given to the characteristics that make one bird superior to another in qualifying for the ideal established. At the same time, it is unwise for poultry breeders to go to extremes by attaching too much importance to numerous minor characters that have no economic significance.

Score-card Judging.—For the purpose of judging chickens according to their standard qualities a scale of points has been developed, whereby each bird may be scored and its various sections given a certain number of points. The total number of points given for each section is a measure of the relative value of that section compared with other sections.

Certain values are given to the weight of the bird as well as to its symmetry and vigor and condition. The theory of score-card judging is to teach students in poultry husbandry and breeders the relative merits of the different sections of the bird as well as to bring out differences that may exist among the birds being judged.

Judging birds by the score card is of great value in impressing upon the mind of the person doing the scoring the merits and demerits of the different shape and color sections. The different sections of the adult chicken are shown in Fig. 2. The scales of points for chickens of the American, Mediterranean, and certain other breeds are given in Table 1. For the scales of points for other breeds the reader should consult the "American Standard of Perfection."

TABLE 1.—SCALE OF POINTS USED IN JUDGING THE VARIOUS CLASSES OF CHICKENS, EXCEPT FRENCH BREEDS, HAMBURG, POLISH, SILKIES, AND GAME, POLISH, AND ROSE-COMB BANTAMS

Character	White		Solid color		Parti-color	
	Shape	Color	Shape	Color	Shape	Color
1. Symmetry	4	..	4	..	4	
2. Weight or size	4	..	4	..	4	
3. Condition and vigor	10	..	10	..	10	
4. Comb	5	..	5	..	5	
5. Beak	2	1	2	1	2	1
6. Head	3	1	3	1	3	1
7. Eyes	2	2	2	2	2	2
8. Wattles	2	..	2	..	2	
9. Ear lobes	2	2	2	2	2	2
10. Neck	3	3	2	4	1	5
11. Wings	5	3	4	4	3	5
12. Back	8	4	7	5	6	6
13. Tail	5	3	4	4	4	4
14. Breast	7	3	5	5	5	5
15. Body and fluff	5	3	5	3	4	4
16. Legs and toes	5	3	5	3	5	3
	72	28	66	34	62	38

Comparison Judging.—While the judging of birds by the score-card method is of great value to beginners and students, experienced judges and breeders usually judge chickens in poultry shows by the comparison method. Each bird is handled individually, but the birds are compared among themselves as units rather than being scored section by section. The same situation exists in the judging of horses, cattle, sheep, and swine; students in animal husbandry are taught to score each animal

individually, but in the livestock shows judging is done by the comparison method without individually scoring each animal.

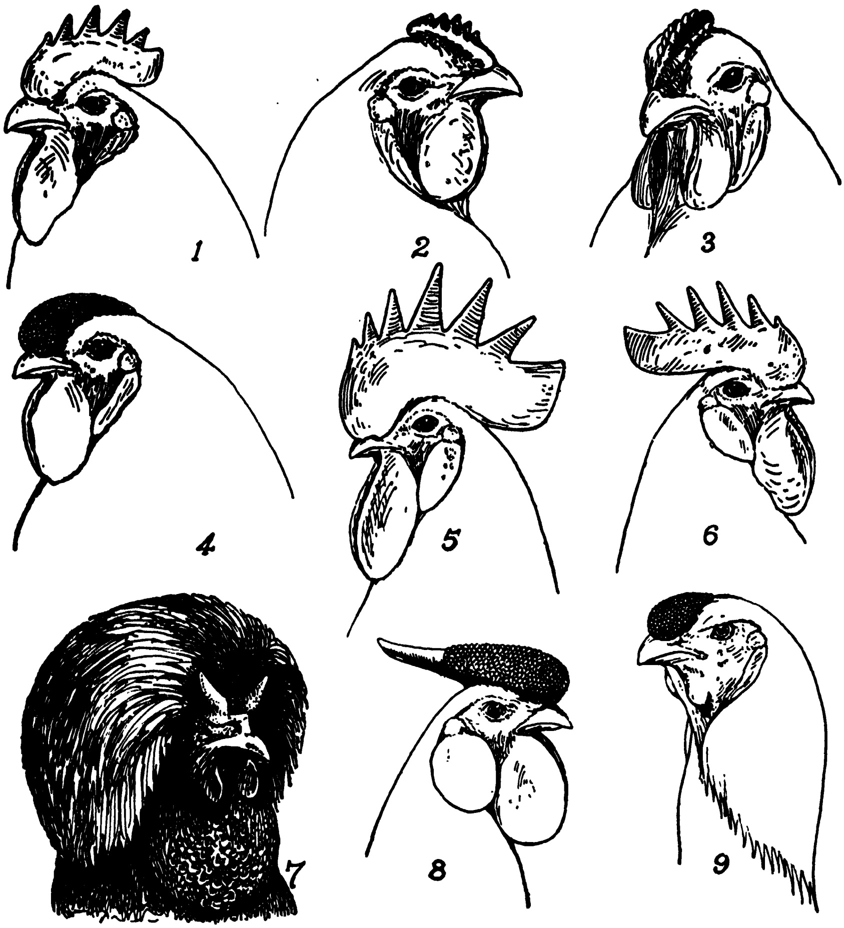


FIG. 8.—Ideal types of combs on males. 1, single (Plymouth Rock); 2 and 3, pea (Brahma); 4, rose (Wyandotte); 5, single (Minorca); 6, single (Leghorn); 7, V-shaped (Houdan); 8, rose (Hamburg); 9, strawberry (Malay). (*U. S. Dept. Agr.*)

DISQUALIFICATIONS AND DEFECTS

In the judging of chickens it becomes obvious that not only are no two chickens alike but also that some of them may have rather serious defects in one or more sections. For instance, a bird may be desirable in every respect except that it has a crooked back or other deformity. A single-comb male bird may be apparently almost a perfect specimen except for a badly lopped comb, illustrated in Fig. 9, or the comb may possess side sprigs, illustrated in Fig. 9. In breeds characterized by having unfeathered shanks there may appear on the shanks featherlike growth or stubs, or bits of down may appear between the toes. The tails

of some birds may depart so much from the normal shape that they are either wry tailed or squirrel tailed, as shown in Fig. 10.

Some of the defects mentioned above are transmitted, and some of them as well as others described in the "Standard of Perfection" are regarded as such serious departures from the ideal shape and color standards desired that they are called "disqualifications." A bird possessing any one of them is barred from winning a prize in the showroom and should not be used in the breeding pen. Some birds may have certain shape and color defects that do not constitute disqualifications but for

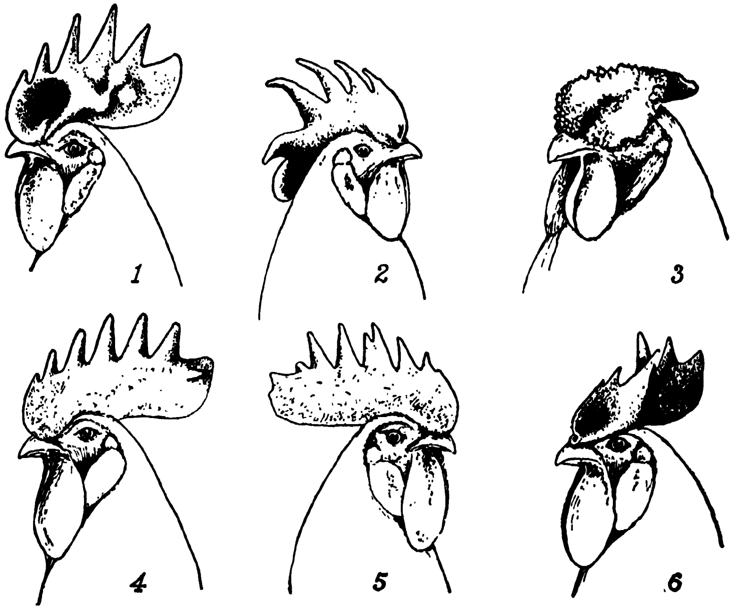


FIG. 9.—Defective types of combs on males. 1, thumb mark; 2, lopped; 3, hollow center; 4 side sprig; 5, uneven serrations; 6, twisted. (*U. S. Dept. Agr.*)

which cuts in scoring are provided. These defects are listed in the "Standard of Perfection" together with the minimum and maximum cuts in points allowed for each defect.

In the selection of breeding stock, disqualifications and defects of major importance should always be kept in mind, especially those that are inherited. Students of poultry culture should know the more general characteristics of the breeds most extensively bred, and with this in mind the following ready-reference list is given here:

Single comb only: Australorp, Jersey Black Giant, Single-comb Black Minorca, New Hampshire, Orpington, Plymouth Rock and Sussex.

Single and rose comb: Ancona, Leghorn, and Rhode Island Red.

Rose comb only: Rhode Island White and Wyandotte.

Pea comb only: Brahma and Cornish.

Red or white ear lobe: Leghorn, Ancona, and Minorca, white; all others mentioned above, red.

White or yellow skin: Australorp, Minorca, Orpington, and Sussex, white; all others mentioned above, yellow.

Black shank: Jersey Black Giant.

Dark-slate shank: Australorp and Black Minorca.

White shank: Orpington and Sussex.

Yellow shank: All others mentioned above.

Feathered or nonfeathered shanks: Brahma, feathered; others, nonfeathered.

Brown or white eggs: Ancona, Leghorn, Minorca, white; others, brown.

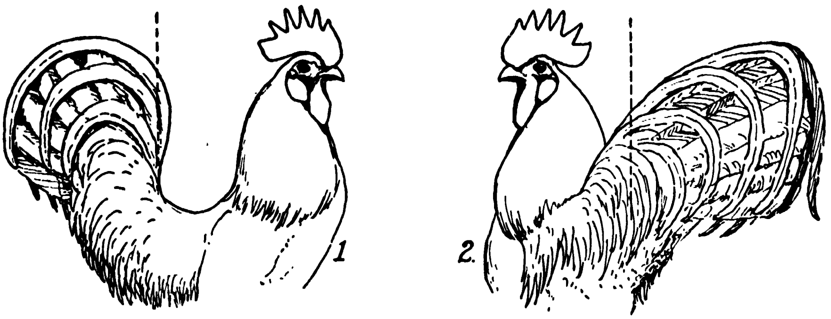
TABLE 2.—THE STANDARD WEIGHTS IN POUNDS OF SOME REPRESENTATIVE BREEDS

Breed	Cock	Hen	Cockerel	Pullet
Ancona	6	4½	5	4
Australorp	8½	6½	7½	5½
Brahma (Light)	12	9½	10	8
Cornish (Dark)	10	7½	8	6
Jersey Black Giant	13	10	11	8
Leghorn	6	4½	5	4
Minorca (S. C. Black)	9	7½	7½	6½
New Hampshire	8½	6½	7½	5½
Orpington	10	8	8½	7
Plymouth Rock	9½	7½	8	6
Rhode Island Red	8½	6½	7½	5½
Rhode Island White	8½	6½	7½	5½
Sussex	9	7	7½	6
Wyandotte	8½	6½	7½	5½

For those engaging in poultry raising for the first time, the choice of breed and variety with which to start sometimes presents a problem. The choice is often a matter of personal interest in plumage coloration, but in most cases consideration should be given to economic qualities. Consideration should be given to the question of the probable demand for market eggs having white or brown shells and to the adaptability of a breed for the production of broilers, fryers, and roasters. Among the breeds listed in Table 2, the Ancona, Leghorn, and Minorcas lay white eggs, and the others lay brown eggs. The Ancona and Leghorn have the same standard body weights and are the smallest of the breeds listed. The Australorp, New Hampshire, Rhode Island Red, Rhode Island White, and Wyandotte have the same standard body weights. The Single-comb Black Minorca, Plymouth Rock, and Sussex have approximately the same standard body weights; the Dark Cornish and Orpington

are approximately the same. The Light Brahma is slightly larger, and the Jersey Black Giant is the largest of all.

Besides taking into consideration the economic qualities of the various breeds the beginner in poultry raising should appreciate the fact that strains within a breed or variety frequently differ a great deal depending upon the extent to which they have been selected, bred, and developed for the various economic and other qualities. In fact, in many respects it is more a matter of the breeding worth of a particular strain in addition to the standard-bred qualities of a breed or variety that



MALES WITH DEFECTIVE TAIL CARRIAGE.
1 SQUIRREL. 2. WRY

FIG. 10.—Males possessing these defects should not be used as breeders. (*U. S. Dept. Agr.*)

should really be the determining factor in deciding upon which breed or variety to keep.

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CHAPTER II

THE BIOLOGY OF THE CHICKEN

The characteristics that distinguish one breed or variety of chickens from another breed or variety are external characteristics which can be seen by the naked eye. Though everyone appreciates the fact that life comes from life, there are too few who realize that the external appearance of a chicken is but the manifestation of certain fundamental processes which take place within the organism.

An insight into the mechanism involved in the transmission of characteristics gives one a much clearer understanding concerning the manner in which a chicken comes to possess certain individual characteristics. Chickens belong to that class of animals called birds, and the outstanding characteristic that differentiates birds from all other animals is that they have feathers. But chickens differ from other birds in certain important respects; and before entering into a discussion of the basis of the reproduction of characteristics from one generation to another, it is well to observe the relationship between chickens and other animals. The classification of the chicken enables one to gain a clearer impression of the fundamental differences between the chicken and other birds.

THE CLASSIFICATION OF THE CHICKEN

The animal kingdom is divided into various phyla (singular, phylum, from the Greek word meaning a "tribe" or "race"). Birds belong to the phylum Chordata, all animals belonging to which possess an axial skeleton, the notochord lying between the nervous system and the alimentary tract; a central nervous system entirely on one side of the digestive canal, and gill slits extending from the pharynx to the exterior.

One subphylum of the Chordata is the Vertebrata, the members of which have an axial skeleton, consisting of skull and vertebral column, which more or less completely replace the notochord. There are also many other distinguishing characteristics, including two kinds of appendages, a brain consisting of five parts, and highly developed eyes and ears.

The subphylum Vertebrata is divided into a number of classes, such as fishes, reptiles, birds, and mammals. Birds belong to the class Aves (from the Latin *avis*, meaning "bird"), the members of which are distinguished by having feathers and a four-chambered heart. They are also warm blooded. All modern birds have no teeth, and so they are placed in the subclass Neornithes.

Next in the classification of birds comes the superorder Neognathae, which comprises all birds with a keeled sternum. In this superorder are included pheasants, chickens, turkeys, guineas, pigeons, ducks, and geese.

Pheasants, chickens, turkeys, and guineas all belong to the order Gallinae. They have compact bodies and well-developed wings and legs, so that they can run and fly without excelling in either direction; the legs and toes are adapted for scratching, and the hind toe is elevated.

The Chicken Belongs to the Pheasant Family.—The suborder Galli includes birds that are cocklike, and included in this suborder is the family Phasianidae, the pheasants, which have tarsi with spurs.

The pheasants all belong to one family comprised of seven subfamilies. The chief distinguishing feature among four of the most closely related subfamilies is the manner of molting the tail feathers. In the first subfamily the molt of the tail is centrifugal; *i.e.*, the feathers molt in regular order from the center to the outside; in the second subfamily the tail molt is centripetal; in the third, the tail molt is from the third pair of feathers, outward and inward; in the fourth, the tail molt is from the sixth pair outward.

In the fowl the tail molt is centripetal in manner, so that the fowl belongs to the second subfamily, called "Phasianinae." There are several different pheasants belonging to this subfamily, but the fowl is the only pheasant with a fleshy comb so that it is placed in a genus called "Gallus," meaning a comb.

The biological classification is as follows:

- Kingdom, animal as distinguished from the plant kingdom.
  - Phylum, chordata: axial skeleton with notochord.
    - Subphylum, vertebrata: skull and vertebral column replacing notochord.
      - Class, Aves: feathered, four-chambered heart, warm blooded.
        - Subclass, Neornithes: without teeth.
          - Superorder, Neognathae: keeled sternum.
            - Order, Gallinae: Gallinaceous birds; fowls.
              - Suborder, Galli: cocklike.
                - Family, Phasianidae: tarsi with spurs.
                  - Subfamily, Phasianinae: centripetal tail molt.
                    - Genus, Gallus: a comb.
                      - Species, domesticus: domestic chicken.

THE STRUCTURE OF THE CHICKEN

From the structural standpoint the chicken is an interesting creature. In common with other birds, it possesses feathers but lacks teeth. It possesses a keeled sternum, is cocklike in appearance, and has tarsi with spurs, a centripetal tail molt, and a comb, which sets it apart from other birds.

In comparison with most of the other domestic animals used for the production of food for mankind, the chicken is a short-lived creature, its utility being spent, for the most part, in a year or two. It is also a fast-living creature, having a relatively high body temperature, a high pulse rate, and a high metabolic rate. It is a rapid breather.

The normal body temperature of chicks varies considerably throughout the day and from day to day. At Cornell University day-old White Leghorn chicks have been observed to have a temperature of 102°F. in the evening and 106°F. in the morning. Rhode Island Red chicks have been shown to have a lower temperature than White Leghorn chicks, the observations having been made at 7 and 10 days of age. No significant differences were observed in the temperatures of male and female

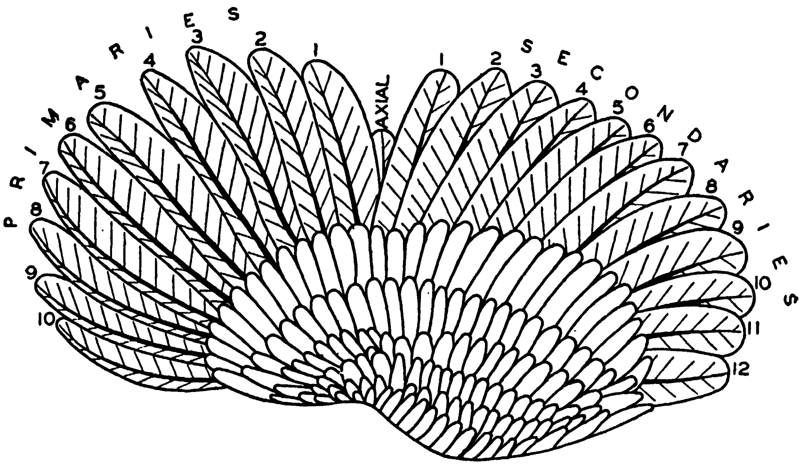

FIG. 11.—The wing feathers of a White Leghorn female showing the axial feather between the primaries and secondaries. (*Warren and Gordon*, 1935.)

chicks. The normal body temperature of the adult chicken during the daytime varies from approximately 105 to approximately 109.5°F., and the daily temperature tends to be lower in cold than in hot weather.

Feathers Arise from Feather Tracts.—Feathers serve the purpose of conserving body heat, keeping out the cold, and protecting the bird against physical injury. Although feathers cover practically all of the body, they arise from certain defined areas of the skin called "feather tracts" or "pterylae." In the normal chicken there are 10 of these feather tracts, feathers developing in the tracts approximately in the following order: shoulder (humeral tract), thigh (femoral or lumbar tract), rump (caudal tract), breast (pectoral or lateral tract), neck (cervical or anterior spinal tract), abdomen (ventral or inferior tract), leg (crural tract), back (dorsal or posterior spinal tract), wing (alar tract), head (caput or head tract). In the Transylvania Naked Neck chicken, neck feathers are absent.

In the males of most breeds, the neck feathers, those over the rear of the back, and the tail feathers are longer and more pointed than in females and are called "secondary sexual" feathers. In certain breeds, such as Campines and Hamburgs, the males have the same type of feather as in the females, except for slightly longer tail feathers; such males are called "hen-feathered" males.

Feather Structure.—A typical feather consists of the quill, which extends throughout the vane of the feather as the shaft or rachis; barbs branching out on each side of the shaft; barbules branching out on each side of the barb; barbicels branching out on each side of the barbule. The Silkie breed of chicken gets its name from the fact that the barbules lack barbicels, giving the feathers a silky appearance.

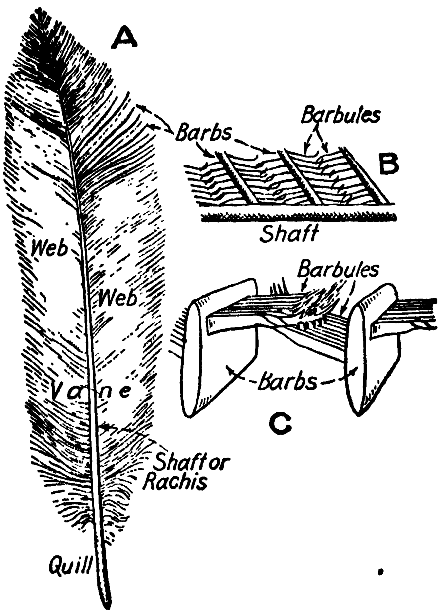

FIG. 12.—The structure of a feather. (*After Evans.*)[1]

The Skin.—The skin of the chicken, of which the comb and the wattles are outgrowths, has no glands except a preen gland or so-called oil gland at the base of the tail. The difference between yellow skin and white skin is due to the presence of lipochrome (fat pigment) in the former and its absence in the latter. In the Silkie the epithelium is unpigmented, but chromatophores are distributed in varying density throughout the connective tissue, periosteum of the bones, and other organs so that when the bird is plucked it appears to be black because of the dark color of the underlying tissues.

Yellow shank color is due to the presence of lipochrome pigment in the epidermis of the shank, and white shank color is due to its absence. Light blue and dark blue shank color occur in breeds or varieties that have a white skin, melanic pigment being deposited in the dermis. Light green and dark green shank color occur in breeds or varieties having yellow skin, melanic pigment being deposited in the dermis. Black shank color is due to the presence of melanic pigment in the epidermis of the shank in breeds with white skin and yellow skin. In white-skinned breeds the bottoms of the feet are white, and in yellow-skinned breeds the bottoms of the feet are yellow.

[1] EVANS, ERNEST, "The Biology of the Fowl," By permission of John Dixon, Ltd., publishers.

The Skeleton.—The skeleton of the chicken is very light in weight, but is very strong as a result of the keel and the fusing together of some of the long bones and the sacral vertebrae. In the "rumpless" fowl the last bone of the tail, called the "pygostyle," the free caudal vertebrae, and the last two vertebrae of the synsacrum are missing. In the "Creeper" fowl the tibia and fibula are much shortened so that the legs are much shorter than in normal fowls.

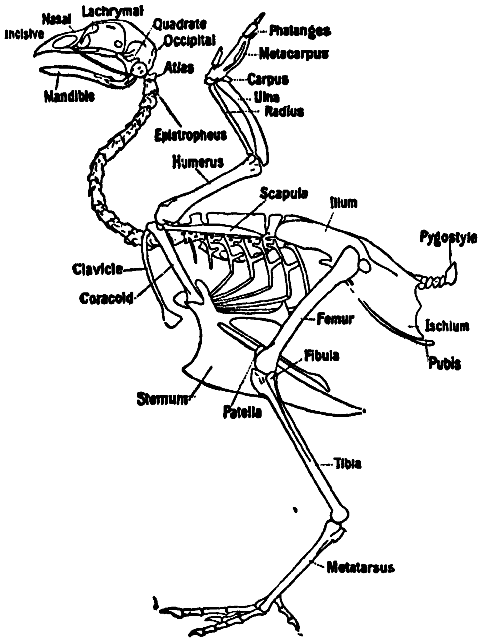

Fig. 13.—The skeleton of a fowl. (*After O. Charnock Bradley.*)[1]

The Respiratory System.—The lungs are fastened dorsally to the ribs and are inexpansible so that the active part of breathing is breathing out or *expiration,* whereas in mammals the active part of breathing is breathing in or *inspiration.* Associated with the lungs of chickens are the air sacs, which also communicate directly with the cavities of several of the long bones of the wings and legs.

The syrinx, or lower larynx, located at the division of the trachea into the two bronchi, is the organ responsible for the chicken's voice.

The Circulatory System and the Blood.—The circulatory system comprises the heart, the arteries, and the veins. The blood is continually in circulation, carrying oxygen and the nutrients to different parts of the body for the development and repair of tissue and carrying away carbon dioxide and waste products. The most numerous of all

[1] Bradley, O. Charnock, "The Structure of the Fowl." By permission of A. and C. Black, Ltd., publishers.

the cells found in blood are the red blood cells or erythrocytes. They are oval and flattened in shape, and each cell contains a nucleus. One of the important constituents of red blood cells is hemoglobin, a protein substance involved in the carrying of oxygen to different parts of the body. The white blood cells or leucocytes are fewer in number than the red blood cells but are much larger. The leucocytes serve the very important function of protecting the body against infection.

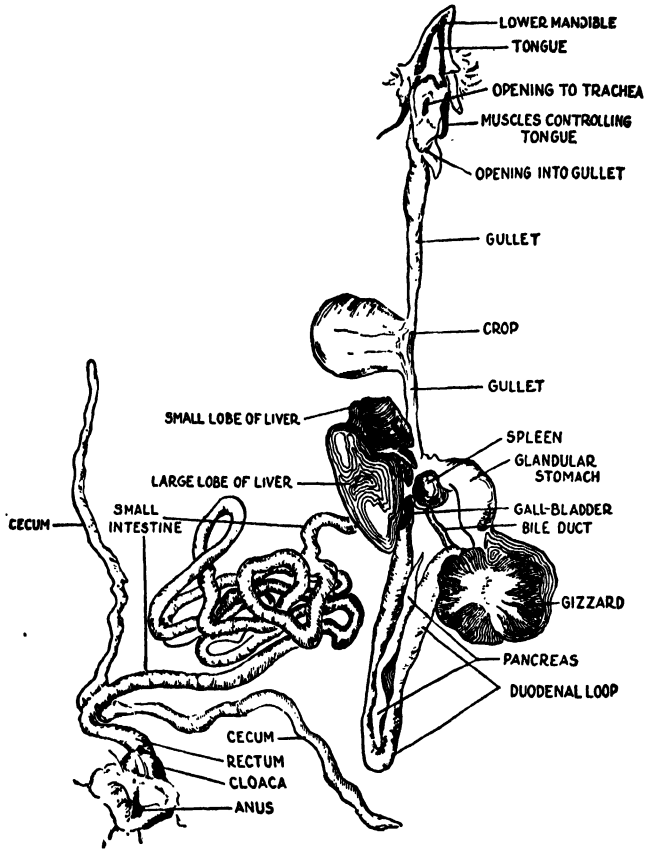

FIG. 14.—The alimentary or digestive tract of a fowl. (*After William A. Lippincott.*)[1]

The Alimentary System.—The alimentary or digestive system of the chicken consists of the organs directly concerned in the reception of feed, its passage through the body, and the excretion of the unabsorbed portion. The digestive system includes the alimentary canal and the accessory organs. The alimentary canal extends from the mouth to the vent and includes the mouth, pharynx, esophagus or gullet, crop, proventriculus or glandular stomach, gizzard, duodenum, small intestine, large intestine,

[1] LIPPINCOTT, WM. A., "Poultry Production." By permission of Lea and Febiger, publishers.

caeca, rectum, cloaca, and vent. The accessory organs include the beak tongue, salivary glands, liver, spleen, and pancreas.

The mouth parts of chickens consist of the upper and lower mandibles and the tongue, all of which are used principally in the apprehension of feed.

The alimentary system of birds differs materially from that of mammals. The absence of teeth in birds is compensated for by the development of a horny beak covering the jaws and by the presence of a gizzard. The pharynx is a muscular region at the back of the mouth and serves to grip the food in the process of swallowing. The gullet or esophagus is an elastic tube, lubricated internally by mucous glands, and it leads to the crop and from the crop again to the glandular stomach or proventriculus. The crop serves as a storage pouch, whereby birds are enabled to eat a large meal "between times."

The gizzard is a very important organ serving to grind the feed and in some respects takes the place of teeth in other animals. It is oval in shape and has a huge development of musculature on two opposite walls with numerous fibers radiating outward from a central tendinous disk. The entrance from the glandular stomach into the gizzard is not far from the exit from the gizzard into the duodenum or duodenal loop. The internal lining of the gizzard is really a secretion, called "pseudo-cuticula." When feed is present in the gizzard the two muscular walls contract in a grinding motion.

The first section of the intestine is called the "duodenum," into which open the two ducts of the pancreas, which lies between the folds of the duodenum.

The liver communicates with the duodenum by means of two or three ducts, one of the ducts being connected with the gall bladder, which stores the bile secreted by the liver. The spleen lies in a triangle formed by the proventriculus, gizzard, and liver and is a small, reddish-brown gland.

The intestine proper is comprised of the small and the large intestine. The small intestine lies in folds in the body, the mode of looping in different birds being definite and constant so that in related birds there are similar patterns of looping. At the junction of the small and the large intestine, or rectum, there is a valve, called "ileocaecal," which prevents a return of feed contents. Arising from the same place are two blind diverticula, the caeca, each usually from 4 to 6 in. in length. The large intestine, or rectum, is relatively short and leads to the cloaca, which also receives the ureters from the kidneys and the reproductive ducts.

Just posterior to the cloaca is the vent, the terminal portion of the alimentary system.

The Urinary System.—The kidneys, of which there are two, lie embedded underneath the hip girdle and are composed of three lobes.

They receive their blood mainly from the renal arteries and return it to the renal veins, which join the great posterior vein, the inferior vena cava, leading back to the heart. The kidneys are very dark colored and serve to strain off from the blood certain deleterious substances in the form of urine. From each kidney the urine is carried to the cloaca in a small tube called the "ureter." It will be seen, therefore, that in birds the urine is mixed with the fecal matter in the cloaca before both are

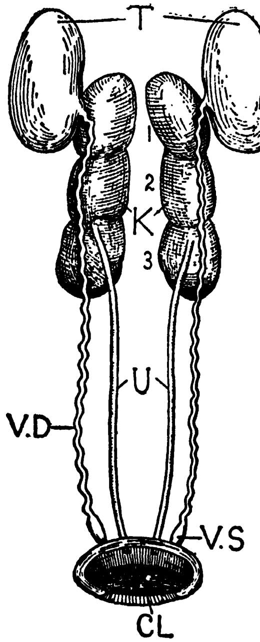

FIG. 15.

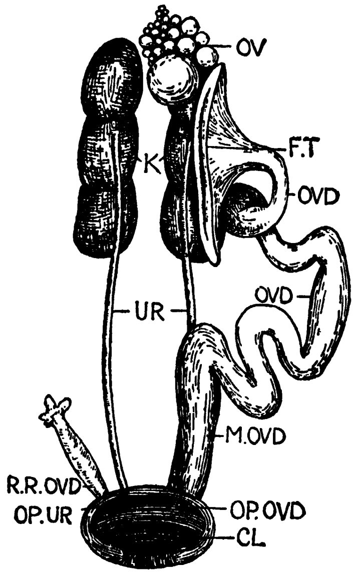

FIG. 16.

FIG. 15.—The reproductive organs and urinary system of the male fowl. *T*, testes; *K*, 1, 2, and 3, lobes of the kidneys; *V.D.*, vas deferens; *U*, ureters; *V.S.*, seminal vesicle for storing spermatozoa; *CL*, cloaca. (*After Thomson.*)[1]

FIG. 16.—The reproductive organs and urinary system of the female fowl. *OV*, ovary; *K*, kidneys; *FT.*, funnel of the oviduct; *OVD*, oviduct; *M.OVD*, uterus of the oviduct; *UR*, ureters; *R.R.OVD*, rudimentary right oviduct; *OP.UR*, opening of the right ureter; *OP.OVD*, opening of the oviduct; *CL*, cloaca. (*After Thomson.*)[1]

extruded, whereas in mammals the urine and feces are extruded from the body separately.

The Regulatory System.—The regulatory system is comprised of a group of small, ductless organs known as endocrine glands. They include the thyroids, parathyroids, pituitary, pineal, adrenal, pancreas, ovary, and testes. A thymus gland develops along the neck of the embryo chick but degenerates the first year after hatching.

In each chicken there is a pair of thyroids lying at the base of the neck, and associated with them are the parathyroids. The pituitary, or

[1] THOMSON, J. ARTHUR, "The Biology of Birds." By permission of The Macmillan Company, publishers.

hypophysis, is a small gland which is situated at the base of the brain. The pineal gland is a very small body located just behind the two cerebral hemispheres. A small adrenal gland is located at the anterior end of each kidney. The pancreas has been mentioned previously, and the ovary and testes are described subsequently.

These endocrine glands produce secretions called "hormones" which are thrown into the blood stream and are carried to various parts of the body. Some of the hormones have been shown to have a pronounced effect on various organs and functions of the body, affecting growth and development in various ways.

The Reproductive System of the Male.—The reproductive system of the male consists of the primary and accessory sexual organs, the former being involved in the production of and the latter in the elaboration of the male reproductive cells. The primary sexual organs are called gonads, and they consist of a pair of testes, or testicles, from each of which there is a tube called "vas deferens," leading to the cloaca, the vas deferens being the accessory sexual organ.

The testes are situated at the anterior ends of the kidneys and are small yellowish-colored bodies, sometimes pigmented. The left testis is usually larger than the right one. Each testis consists of a large number of slender tubes, called seminiferous ducts, from the linings of which the reproductive cells are given off, whence they are conducted to the vas deferens. It is while the spermatozoa are in the vas deferens that they acquire the power of motility.

The vasa deferentia open into ducts which lie directly over a groove in a rudimentary copulatory organ.

The Reproductive System of the Female.—The reproductive system of the female consists of primary and accessory sexual organs, the ovary and the oviduct, respectively. The ovary is involved in the production of the female reproductive cells, called "ova." The oviduct serves to carry the ova from the ovary to the cloaca. During the passage of the ova through the oviduct the secretion takes place of the different kinds of albumen or white of the egg, shell membranes, and shell to make the completed egg.

The ovary, or female gonad, is single and is on the left side of the body, although during embryonic development a right gonad and oviduct also develop but gradually degenerate until at hatching time only rudiments remain. Occasionally birds are observed that have two functional ovaries and oviducts.

In a typical female the ovary is situated to the left of the median line of the body just posterior to the lungs and at the anterior end of the kidney and is attached to the dorsal wall of the body cavity. In an inactive condition the ovary appears as a small, whitish mass of irregular

contour, whereas in an active condition it appears as a yellowish cluster of cells of varying size.

The oviduct is a large coiled tube occupying a large part of the left half of the abdominal cavity and is suspended from the dorsal body wall. At the anterior end of the oviduct is its mouth which is spread out beneath the ovary to receive the ova or yolks when they are ready to leave the ovary. The posterior end of the oviduct connects with the cloaca, from which the completed egg is expelled.

The oviduct consists of the following five parts: funnel or infundibulum, magnum or so-called albumen-secreting portion, isthmus, uterus, and vagina.

THE FORMATION, STRUCTURE, AND PHYSICAL ASPECTS OF THE EGG

All life in the higher organisms is perpetuated through the egg. The development of the embryos of mammals takes place within the body of the female, whereas the development of the chick embryo takes place, for the most part, outside the female body. It is for this reason that the chicken egg is such a large reproductive cell as compared with the reproductive cell or egg of a mammal. In the case of the mammalian embryo its nourishment is obtained directly from its mother. In the case of the chick embryo its nourishment is obtained from the different parts of the egg, but the egg, is, nevertheless, a reproductive cell.

The Formation of the Egg.—Each cell, or yolk, with its vitelline membrane as a covering, is an ovum and is contained in a very thin envelope called the "follicle," which is attached to the ovary by a very slender stalk. Embedded in the surface of the yolk under the vitelline membrane is the nucleus, or germinal vesicle, or germ spot.

The yolk granules are secreted in concentric layers, beginning with a layer of light yolk, which forms a flask-shaped structure beneath the germinal disk. Subsequent layers of yolk all tend to be dark in color in eggs laid by birds fed ad libitum an all-mash diet, according to the Kansas Experiment Station. Birds fed large amounts of feed rich in xanthophyl, especially during short periods, lay eggs containing alternate light and dark colored layers of yolk. The accumulation of yolk apparently proceeds at the same rate day and night. As the yolk increases in size the follicle in which it is contained enlarges, and, when the yolk is ready to be liberated from the ovary, the follicle bursts along a streak called the "stigma." Subsequently, the ruptured follicle degenerates. The liberation of the yolk from the ovary is termed "ovulation."

Ovulation may or may not be accompanied by the grasping of the yolk by the mouth of the oviduct. If the two processes do not take place simultaneously, the yolk falls into the body cavity of the hen, whence it is subsequently recovered by the mouth of the oviduct.

Immediately upon being grasped by the mouth of the oviduct, the yolk is forced through the oviduct by ciliary action or by peristalitic movements of the walls of the oviduct. During its passage through the oviduct, the yolk is surrounded by albumen, which is secreted by glands in the walls of the oviduct. The differentiation of the albumen or white

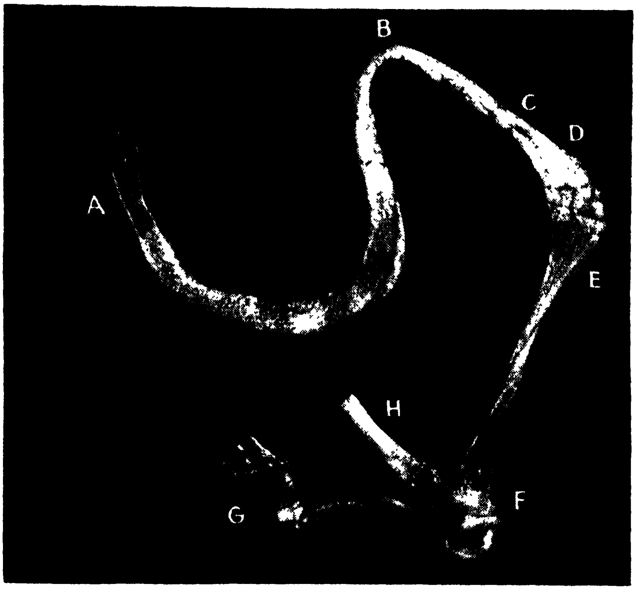

FIG. 17.—The more important regions of the oviduct are as follows: mouth; *A* to *B*, the magnum; *B* to *C*, the isthmus; *C* to *E*, the uterus; *E* to *F*, the vagina; *G*, the rudimentary right oviduct; *H*, the large intestine. (*Asmundson and Burmester*, 1936.)

of the egg into four distinct layers occurs, for the most part, after the yolk has entered the uterus, although some differentiation usually starts in the isthmus. The shell is secreted in the uterus. The formation of the egg is completed by the time it reaches the vagina.

TABLE 3.—THE APPROXIMATE LENGTH OF DIFFERENT SECTIONS OF THE OVIDUCT, THE APPROXIMATE PER CENT OF ALBUMEN SECRETED IN EACH OF THREE SECTIONS, AND THE APPROXIMATE TIME SPENT BY THE YOLK IN DIFFERENT SECTIONS
(Compiled from data of Warren and Scott, 1935, and Asmundson and Burmester, 1936)

Section of oviduct	Approximate length, centimeters	Per cent of albumen secreted	Approximate time spent by yolk
Mouth	5.0		
Funnel	4.0	....	18 min.
Magnum	33.0	40 to 50	2 hr. 54 min.
Isthmus	10.0	10	1 hr. 14 min.
Uterus	12.0	40 to 50	20 hr. 40 min. (Uterus and Vagina)
Vagina	12.0	....	

The table on page 45 gives the approximate length of the different sections of the oviduct, the approximate per cent of albumen secreted in each of the three sections involved in albumen secretion, and the approximate time spent by the yolk in each section.

It seems quite certain that in the great majority of cases eggs are laid small end first and that of the relatively few that are laid large end first, some become turned end for end in the uterus, probably as the result of the small end of the egg's becoming projected deeply into the blind sac of the uterus during the act of laying.

The Structure of the Egg.—The completed egg is of complex structure and is comprised of the following six main parts: germ spot, yolk, vitelline membrane, white, shell membranes, and shell.

The chick originates in the germ spot, but all of the yolk and white of the egg contribute to the nourishment of the embryo during incubation and of the chick shortly after being hatched. The germ spot is always on the upper side of the yolk in an egg in resting position, because the portion of the yolk in which the germ is located is of lower specific gravity than the rest of the yolk.

The yolk is composed of concentric layers of light- and dark-yolk granules, the layers of light yolk being much thinner than the layers of dark yolk. The difference between the light and dark yolk is accounted for by the larger size of the dark yolk granules and by the fact that the light yolk granules contain relatively more water.

The vitelline membrane, surrounding the yolk, is composed of three layers: a noncellular layer on the inside, a layer of epithelium in the middle, and a layer of connective tissue on the outside.

The white is made up of four parts: the chalazas, two layers of thin white, and a layer of thick white. The two chalazas are dense cordlike structures twisted in opposite directions and are attached on opposite sides of the yolk to a thick layer of white surrounding the yolk. The chalazas serve the important function of mooring and steadying the yolk approximately in the center of the egg. Surrounding the chalaziferous layer of thick white is a layer of thin white. This layer of thin white is surrounded by a layer of thick white, which in turn is surrounded by a layer of thin white. Thick white differs from thin white in one important respect at least in that it contains a much higher proportion of a protein possessing the properties of mucin. The thick white comprises about 50 to 60 per cent, the inner thin white about 20 to 25 per cent, and the outer thin white about 20 to 25 per cent of the total white.

There are two shell membranes surrounding the white, the inner one being considerably thinner than the outer one. The inner and outer shell membranes adhere closely to each other except at the large end of the egg, where they are usually separated to form the air cell, although in

some eggs the air cell is in some other place. The shell membranes are composed of organic fibers and are porous. In a normal egg, shortly after it is laid, the air cell is approximately the size of a dime.

The shell is composed of four layers and a cuticle, or bloom. The innermost layer or membrane consists of minute calcareous particles; the second layer consists of minute particles of calcium carbonate; the third, or mammilla, layer consists of large spheres of calcite; the outer layer is composed of crystals of calcium carbonate arranged with their long axes perpendicular to the surface. The cuticle, or bloom, on the outside of the egg, is apparently structureless. The four layers of the shell and the bloom are porous, thus allowing for the passage of air and moisture.

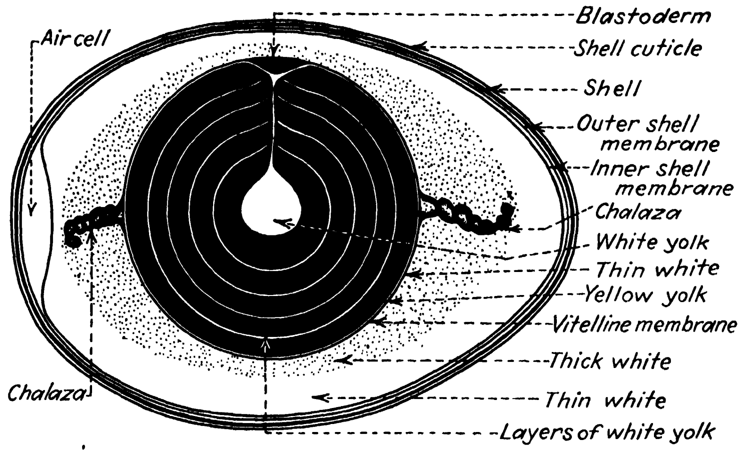

FIG. 18.—Showing the structure of an egg. (*Modified from Schaible, Davidson, and Moore 1936.*)

The porosity of the shell membranes and the shell allows the embryo to respire by the diffusion of carbon dioxide out and oxygen in.

The shell of eggs range in average thickness from about 0.30 to 0.35 mm. and a range in breaking strength from approximately 4.40 to about 4.80 kg.

Physical Aspects of Eggs.—Eggs laid by different hens often differ greatly in their shape, size, and color.

From the standpoint of shape, most eggs are ovate with one end larger and more blunt than the other. Although the eggs laid by a flock may differ markedly in shape, the eggs laid by an individual possess a characteristic shape. The general shape of the egg appears to be determined largely by the amount of white secreted in the magnum section of the oviduct and by the caliber of the lumen of the magnum and isthmus and the muscular activity of their walls. To a large extent the shape of the egg is determined in the isthmus.

The size of an egg obviously is determined by the collective weights of its component parts. From observations on eggs laid by different flocks it has been observed that the white contributes approximately 59 per cent, the yolk approximately 30 per cent, and the shell approximately 11 per cent of the total egg weight. But the percentage weights of the different parts of the egg and the weight of the egg itself varies during the annual production record of an individual. Also, eggs laid in hot weather usually have relatively less white than eggs laid in cold weather. The comparatively small size of eggs laid by early maturing pullets is due, to some extent at least, to the relatively small yolk. As a matter of fact, two factors of major importance in determining the size of egg laid by birds of all ages are the size of the yolk that is formed and the size of the oviduct of the bird. Egg size is also affected by the position of the egg in a clutch, each succeeding egg in the clutch usually showing a progressive decrease in weight. In many flocks it has been demonstrated that there is a tendency for the best producers during the first year of laying to lay relatively smaller eggs than the poorer producers, the best producers tending on the average to be smaller in body size than the poorer producers. It has also been shown that in many flocks the largest individuals tend to lay, on the average, larger sized eggs than the smaller individuals, apparently because the largest birds tend to form larger yolks and have larger oviducts than the smaller hens.

The color in the shell of brown-shelled eggs seems to be due to one type of pigment, the principal representative of which is oöphorin. Apparently, the pigment is secreted in the isthmus and uterus sections of the oviduct. Although each hen lays eggs the shells of which are approximately the same shade, the degree of pigmentation tends to decrease as egg production increases.

Abnormal eggs are usually the result of some physiological disturbance taking place in the oviduct. Dwarf eggs are often produced following the ovulation of yolks that escape into the body cavity or after the rupture of the vitelline membrane, ovulation or yolk material giving the oviduct the necessary stimulus to begin secreting the white. The most common cause of double-yolked eggs is due to a yolk in the oviduct becoming arrested in its progress down the oviduct until another yolk catches up with it, both yolks finally being enclosed in the same shell membranes and shell. Triple-yolked eggs and "eggs within eggs" usually result from much the same circumstances that result in the production of double-yolked eggs. Eggs containing blood, blood spots, or meat spots are usually the result of the rupture of blood vessels or the tearing away of some of the tissue of the lining of the oviduct. Soft-shelled eggs may be those that are laid prematurely, or they may be due to some physiological disturbance in the functioning of the oviduct.

PHYSIOLOGICAL ASPECTS OF SEXUAL DIFFERENTIATION

The fundamental differences between the sexes are the result of the adaptation of the male for the production of male reproductive cells and of the female for the production of female reproductive cells or eggs. The male reproductive system is structurally different from that of the female. But the sexes differ not only in the structure of their reproductive organs but also in many other respects. Thus there are primary sex differences involving the sex organs, which have been discussed previously, and secondary sex differences involving other organs as well as various characters and functions peculiar to each sex. Many of these secondary sex differences are due to secretions, called hormones, produced by the gonads and other endocrine glands. Hormones are of the greatest importance in many physiological processes that take place in the chicken.

Sex Differences in Comb, Wattles, and Spurs.—The male usually has a larger comb and wattles than the female and possesses spurs, which are usually lacking in the female.

It has been shown that when either combs or wattles were transplanted from one individual to another of the opposite sex, the operation having been performed on chicks 3 days old, the growth of the comb and wattles was greater when male than when female chicks were the recipients. The host rather than the donor was the determining factor as to the ultimate size attained by the comb and wattles.

During the growth of the cockerel, his gonads, or testes, increase in size as does his comb, a quantitative relationship existing between their development. The size of comb attained by a male is determined to a considerable extent by the degree of cell activity of the gonad, although sunlight also affects the ultimate size attained, birds kept out of sunlight having larger combs than otherwise.

When the right and left testes of a male are removed by operation, to produce a capon, the comb and wattles are considerably reduced in size. If only one testis is removed by operation, the other testis frequently increases in size until it is as large as both testes in a normal male of the same age, and the comb develops normally.

When the right and left testes are removed from a cockerel, and tissue from the ovary of a female is grafted on the site of one of the removed testis, the cockerel has the female type of comb. When the ovary is removed from a very young female, a compensatory right gonad develops having the appearance of a testis, and the comb and wattles of the female develop as large as in normal males. When the compensatory gonad is destroyed by cauterization, the comb and wattles remain small, and spurs develop.

The testis produces a hormone which is responsible for the ultimate size attained by the comb, wattles, and spurs.

Sex Differences in Blood Cells.—The adult male has approximately one million more red blood cells, or erythrocytes, per cubic millimeter of blood than the adult female, the total number recorded being approximately 3,800,000 for the male and 2,800,000 for the female. The male hemoglobin values also exceed those of the female.

Sex Differences in Growth Rate and Body Size.—In practically all breeds of chickens the male grows faster and attains a larger size than the female, in some breeds the difference in adult weight being quite pronounced. In many breeds the males have significantly longer wing and leg bones than the females. Hormones produced by the ovary may perhaps have some effect on body size, although the sex difference in body size seems to be due to other factors, which are discussed later. A hormone produced by the testis affects body size, for when a young cockerel is castrated by removing his testes he continues to grow for a longer period than an uncastrated cockerel, thus attaining a larger size. Moreover, the capon's flesh remains tender because less connective tissue develops but more fat is deposited than in an uncastrated mature male.

Sex Differences in Feather Structure.—In most breeds the male differs from the female by having longer and more pointed lower neck, saddle, and sickle and tail feathers, the development of most of these secondary sexual characters being controlled by the testes. The ovary secretes a hormone which prohibits the development of the pointed nature of these secondary sexual feathers of the males. Males from which both testes have been removed, making the bird a capon, have longer secondary sexual feathers than uncastrated males. The removal of one testis or both testes and the implantation of ovarian tissue on the site of the removed testis result in the resumption of female type of plumage, the change occurring when the male molts after being operated upon.

The existence of normal hen-feathered males, such as Campines, demonstrates that female-type plumage is not always dependent upon the presence of the ovary or female gonad. The castration of a normal hen-feathered male results in his becoming completely cock feathered. Gonad grafts from hen-feathered males implanted in castrated cock-feathered males results in cock feathering, whereas gonad grafts from cock-feathered males implanted in castrated hen-feathered males results in hen feathering.

The removal of the ovary (left gonad) results in the female assuming cock feathering, although these cock-feathered females later assume hen feathering owing to the influence of the compensatory right gonad which develops after the ovary is removed. The destruction of the compensatory gonad results in the female assuming capon feathering. Testicular tissue added to ovarian tissue in females does not produce any change in the female type of plumage.

A hormone secreted by the thyroid glands influences the development of hen feathering. The theory has been advanced that the ovary stimulates the thyroid to a higher level of activity than the testis, the hormone secreted by the thyroid suppressing the development of the secondary sexual feathers as found in the normal male.

Hermaphrodites and Gynandromorphs.—A hermaphrodite is an animal possessing male and female gonads which function in the production of male and female reproductive cells. In the chicken the nearest approach to such a condition has been chickens possessing both a male and female gonad, but there are no reports of both gonads functioning.

A gynandromorph chicken is one in which one part of the body is male and the other part female.

Is Sex Reversal Possible?—Although several cases of sex reversal in nature have been reported, there appears to be no single case concerning which it can be stated unequivocally that the sex was reversed, including the functional activity of the male and female gonads. Nevertheless, experimental evidence has been secured which indicates that under certain conditions a normal female may be transformed into an anatomical male and a normal male transformed into an anatomical female. Female chicks from which the ovary was removed as early as the seventh and eighth day after hatching developed a right gonad containing male reproductive cells. The injection of a female hormone called "theelin" into eggs after 24 hr. of incubation has demonstrated the possibility of reversing the sex of male embryos so that they become anatomical females, but no anatomical females that were genetically males have as yet been known to reproduce. Apparently the feasibility of reversing the sexes in the chicken depends upon a certain balance of interaction between male and female sex hormones and upon the balance of interaction between sex hormones and genes, the nature and effects of which are discussed after the next paragraph.

The Sex Ratio.—By the term "sex ratio" is meant the percentage of males of the total number of chicks in a given population. The normal sex ratio is approximately 49.0, although the percentage of males in small groups of chicks may vary somewhat. The various physical characters of eggs apparently have no bearing on the sex ratio, nor have prenatal nor postnatal mortality or such factors as inbreeding, crossbreeding, and the previous egg production of the dam. Also, the tendency on the part of certain females to produce a preponderance of either sex apparently is not inherited.

THE GENETIC BASIS OF REPRODUCTION

With respect to the numerous characters that the chicken possesses, it has been demonstrated that many of them are transmitted from parent

to offspring by means of a definite mechanism involving certain constituents of the reproductive cells of the male and the female. It has been pointed out previously that the reproductive cells are produced by the gonads, the testes of the male and the ovary of the female. The male reproductive cells are called "spermatozoa" (singular, spermatozoon). The female reproductive cells are called "eggs," or "ova" (singular, ovum).

The Significance of Mating.—The act of copulation between male and female brings about the union of a spermatozoon and an ovum. At the time of copulation the male ejects sperm containing spermatozoa into the cloaca of the female, the spermatozoa traverse the oviduct, and one spermatozoon fertilizes the germ spot in the ovum almost as soon as the ovum, or yolk, has been grasped by the mouth of the oviduct. The union of the spermatozoon and ovum is necessary in order that offspring may be produced, but the really significant thing that mating accomplishes is to produce new combinations of hereditary characters, a subject discussed more fully later.

Chromosomes the Vehicles for the Transmission of Characters.—From the standpoint of the inheritance of characters, the reproductive cells are spoken of as gametes, the term "gamete" meaning a spouse. The spermatozoon is the male gamete, and the ovum is the female gamete. The fertilization of the female gamete by the male gamete produces the fertilized egg, which is termed a "zygote," meaning yoked together. Thus, a male and female gamete unite to produce a zygote, which develops into the chick.

Each gamete contains little threadlike bodies called "chromosomes," which are transmitted from parent to offspring.

The male zygote has one more sex chromosome than the female zygote. The sex chromosomes in any species are apparently always associated with sex and may be a factor in its determination, hence their name. The rest of the chromosomes are called "autosomes," and they are always in pairs in the zygote. The male chicken, therefore, has a certain number of pairs of autosomes and two sex chromosomes, whereas the female has the same number of pairs of autosomes and one sex chromosome.

Since the male has a certain number of pairs of autosomes and two sex chromosomes, it is obvious that the zygote from which he developed was produced by the union of two gametes each of which contained half the number of autosomes and one sex chromosome. Since the female has a certain number of pairs of autosomes and one sex chromosome, it is obvious that the zygote from which she developed was produced by the union of a gamete containing half the number of autosomes and one sex chromosome and a gamete containing half the number of autosomes but no sex chromosome.

Up to the present only one phase of the reproductive cycle has been discussed, the union of a gamete of paternal origin with a gamete of maternal origin. The other phase of the reproductive cycle consists in the development of the gametes from the zygotes. For the sake of simplicity, the behavior of the sex chromosomes in the processes involved is omitted from this brief discussion. Each zygote gives rise to numerous germ cells. The chromosomes in each germ cell unite in pairs, a particular chromosome of paternal origin pairing with a similar chromosome of maternal origin. The chromosomes then split lengthwise twice. After the second splitting is completed, the germ cell divides, half of the chromosomes going into one cell and half into the other; each cell contains, therefore, half as many chromosomes as the germ cell. These cells, each containing the half number of chromosomes, are called gametes.

The female is spoken of as being heterogametic, since the female zygote produces unlike gametes with respect to the sex chromosome.

A very important point always to be kept clearly in mind is that when the gamete of female origin containing the sex chromosome unites with a gamete of male origin, the zygote produced is a male, whereas when the gamete of female origin that does not contain the sex chromosome unites with a gamete of male origin, the zygote produced is a female. Another fundamental point always to be kept clearly in mind is that either of the unlike gametes of female origin may mate with either of the like male gametes.

The chromosomes are the bearers of the determiners of hereditary characters, but since there are hundreds of characters and only a certain number of pairs of autosomes and one or two sex chromosomes, according to the sex, it is obvious that each chromosome must contain many determiners. The chicken has at least 17 but more probably about 40 pairs of autosomes. The determiners of hereditary characters are called genes, each chromosome containing many of these small units. It is the genes that give rise to such characters as single comb, white skin, black plumage, broodiness, hatchability, and egg production.

Sex-linked Inheritance.—Many characters that fowls possess are inherited equally from sire and dam. The genes giving rise to such characters are borne on the numerous pairs of autosomes common to both sexes, half of the autosomes being of paternal origin and half of maternal origin in the case of each individual chicken.

There are certain characters, however, that are transmitted from the dam to her sons but not to her daughters, although these same characters are transmitted from the sire to his sons and daughters alike. Characters that are transmitted from dam to son only are called sex-linked characters because the genes that determine such characters are borne on the sex chromosomes.

The results secured from a mating of a Rhode Island Red male and a Barred Plymouth Rock female serve to illustrate the manner in which sex-linked characters are inherited. The male offspring of such a mating are barred, and the female offspring are black, although some of the pullets may have red in the neck and breast feathers, but black is the predominant plumage color. The fact that the male offspring only of this mating are barred demonstrates that the gene that determines the barring pattern in the plumage is borne on the sex chromosome. The Barred Plymouth Rock female's gametes containing the sex chromosome, upon uniting with the Rhode Island Red male's gametes, each of which also contains the sex chromosome, produce male zygotes inasmuch as they each contain two sex chromosomes. On the other hand, the Barred

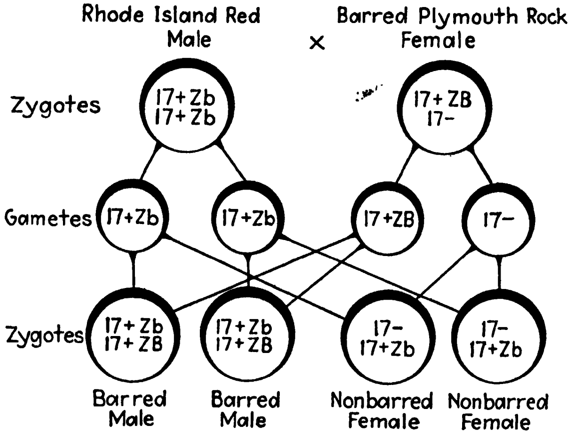

FIG. 19.—The Rhode Island Red male has at least 17 pairs of autosomes and 2 sex chromosomes, designated *Z*, associated with each of which is the gene *b* for nonbarring. The Barred Plymouth Rock female has at least 17 pairs of autosomes but only one sex chromosome *Z*, associated with which is the sex-linked gene *B* for barring, which is dominant to nonbarring. The male progeny are barred whereas the female progeny are nonbarred.

Plymouth Rock female's gametes lacking the sex chromosome, upon uniting with the Rhode Island Red male's gametes, each of which contains the sex chromosome, produce female zygotes, inasmuch as they each contain only one sex chromosome.

Barring is sex-linked and is transmitted from the barred female parent to her male offspring only. The gene for barring is dominant to the gene for nonbarring, as in the Rhode Island Red male. The term "dominant" simply means that the effects produced by one gene suppress the effects of another gene. Barring is said to be dominant to nonbarring, for although the Rhode Island Red is predominantly red in plumage color its plumage is nonbarred. In illustrating the results secured from matings the capital letter is always used to denote the dominant character, so that *B* is used to denote barring, and *b* nonbarring, the latter being the recessive character.

In the case of the chicken the inheritance of sex is commonly referred to as the *WZ* type, the symbol *W* denoting the absence of a sex chromosome in one gamete and *Z* the presence of a sex chromosome in the other gamete of the two that unite to produce a female. In diagrams illustrating the inheritance of sex-linked characters, however, the customary way of indicating the absence of a sex chromosome is by the use of a dash, so that the female zygote is expressed as *Z*—, as far as the sex chromosomes are concerned. The male zygote is expressed as *ZZ*, as far as the sex chromosomes are concerned.

Since the gene for barring is borne on the sex chromosome, the gene *B* is illustrated in company with *Z*, the sex chromosome, in diagrams illustrating sex-linked inheritance. Since the Rhode Island Red is nonbarred,

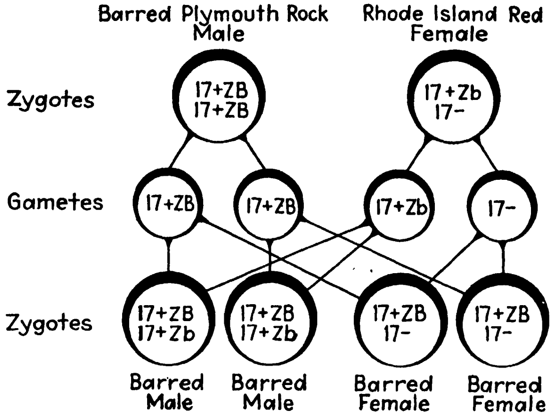

FIG. 20.—The Barred Plymouth Rock male has at least 17 pairs of autosomes and 2 sex hromosomes, designated *Z*, associated with each of which is the sex-linked gene *B* for arring. The Rhode Island Red female has at least 17 pairs of autosomes but only one sex aromosome *Z*, associated with which is the gene *b* for nonbarring. The male and the male progeny are barred.

ıe male zygote is designated as *ZbZb* in so far as the sex chromosomes ıd the nonbarring genes are concerned. In order to simplify the disussion on sex-linked inheritance, no further reference is made to the autosomes, since they do not affect the situation. The male zygote produces one kind of gametes only, *Zb*. The zygote of Barred Plymouth Rock female is designated *ZB*—. This female zygote produces two kinds of gametes, *ZB* and —.

The gametes *Zb* from the male upon uniting with the gametes — from the female produce *Zb*— zygotes, which develop into nonbarred (black) females because the gene for barring is lacking and there is only one sex chromosome present. The gametes *Zb* from the male upon uniting with the gametes *ZB* from the female produce *ZbZB* zygotes, which develop into barred males because the gene for barring is present and two sex chromosomes are also present. The gene for barring is sex-linked, since

it is transmitted from the barred dam to her male offspring only. A true test of the sex linkage of the gene for barring is to mate a Rhode Island Red male to some of the nonbarred (black) females obtained from the original cross (Rhode Island Red male × Barred Plymouth Rock female);

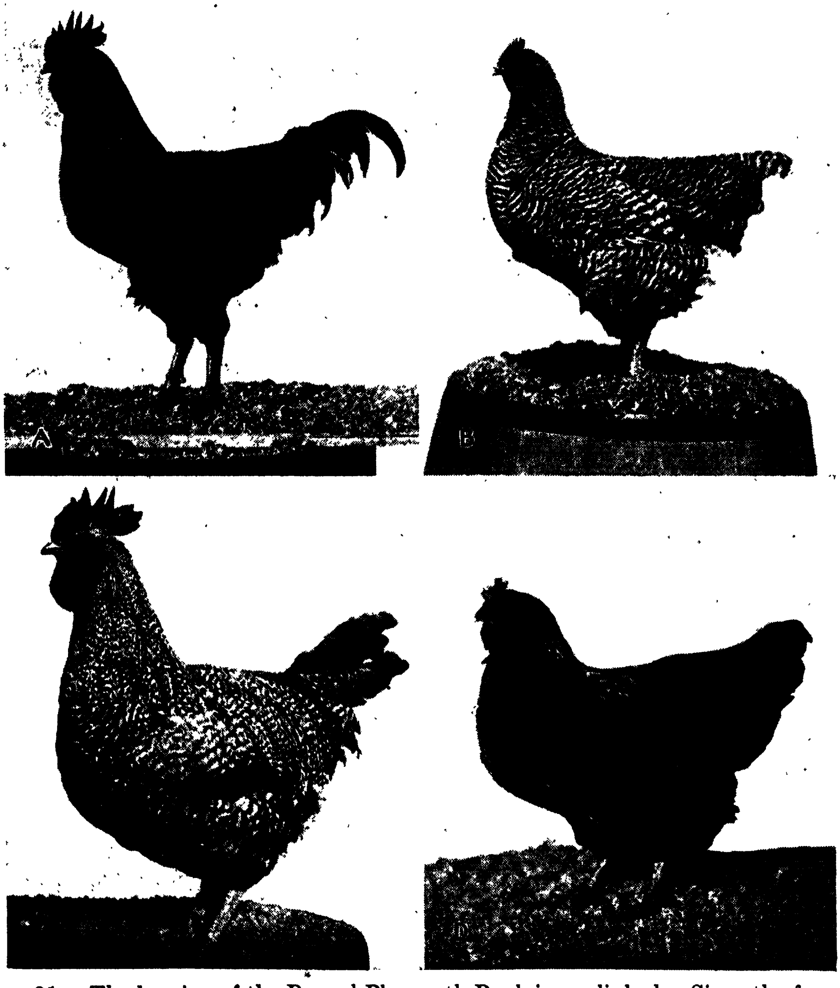

FIG. 21.—The barring of the Barred Plymouth Rock is sex-linked. Since the female is heterozygous for sex and has one sex chromosome only, it is transmitted to her sons but not to her daughters so that her adult sons are barred but her adult daughters are black. This illustration shows the Rhode Island Red sire (*A*), the Barred Plymouth Rock dam (*B*), the barred son (*C*), and the black daughter (*D*). (*U. S. Dept. Agr.*)

the offspring, both male and female, of this backcross mating are nonbarred, showing that the nonbarred (black) females did not carry the gene for barring.

When a Barred Plymouth Rock male is mated with a Rhode Island Red female, all of the offspring, both male and female, are barred. The

zygote of the Barred Plymouth Rock male $ZBZB$ produces one kind of gametes only, ZB. The zygote of the Rhode Island Red female $Zb-$ produces two kinds of gametes, Zb and $-$.

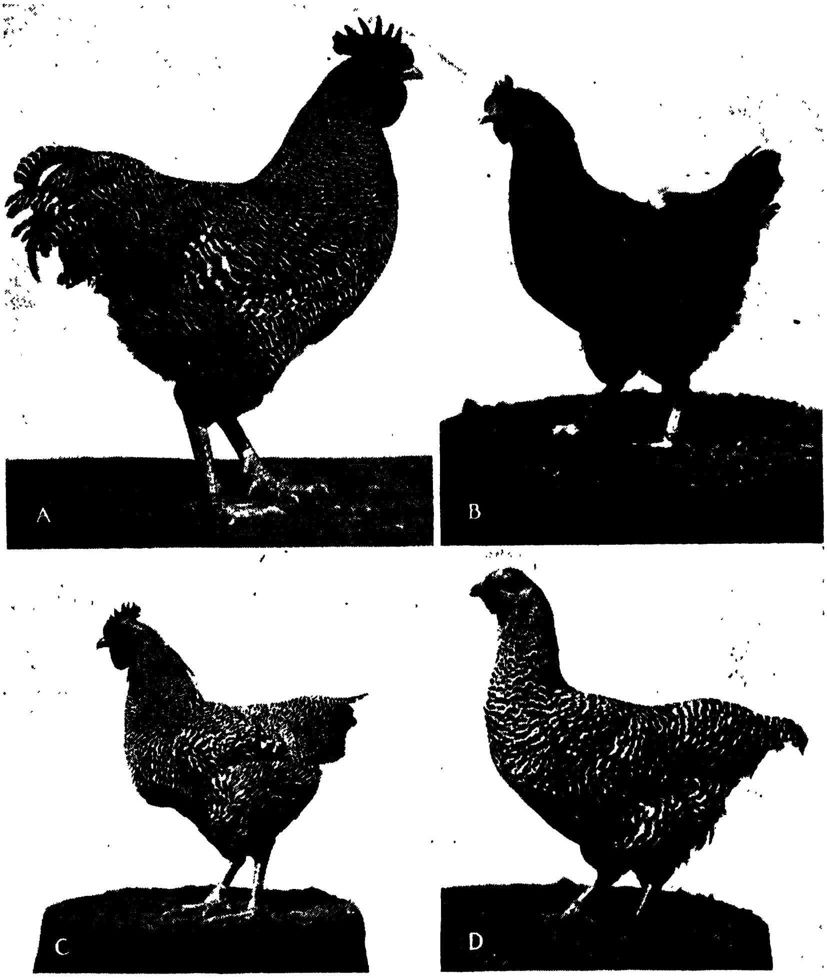

FIG. 22.—The barring of the Barred Plymouth Rock is dominant to nonbarring. When a Barred Plymouth Rock male is crossed with a Rhode Island Red female, the male and female adult progeny are barred because the sire has a gene for barring on each of his two sex chromosomes, one of which is transmitted to each of his sons and the other to each of his daughters: *A*, Barred Plymouth Rock sire; *B*, Rhode Island Red dam; *C*, adult son; *D*, adult daughter. (*U. S. Dept. Agr.*)

The gametes ZB from the male upon uniting with the gametes $-$ from the female produce $ZB-$ zygotes, which develop into barred females because the gene for barring is present and there is only one sex chromosome present. The gametes ZB from the male upon uniting with the gametes Zb from the female produce $ZBZb$ zygotes, which develop into barred males because the gene for barring is present and two sex chromo-

somes are also present. The Barred Plymouth Rock male transmits the gene for barring to his daughters as well as his sons.

Distinguishing Sex at Hatching Time.—An interesting feature about the inheritance of some of the sex-linked characters is that the sexes of the chicks can be distinguished at hatching time.

The males of several different breeds and varieties may be mated with Barred Plymouth Rock females for the purpose of producing chicks which, at hatching time, can be separated according to sex by the down pattern. The adult plumage of the sexes also differs markedly.

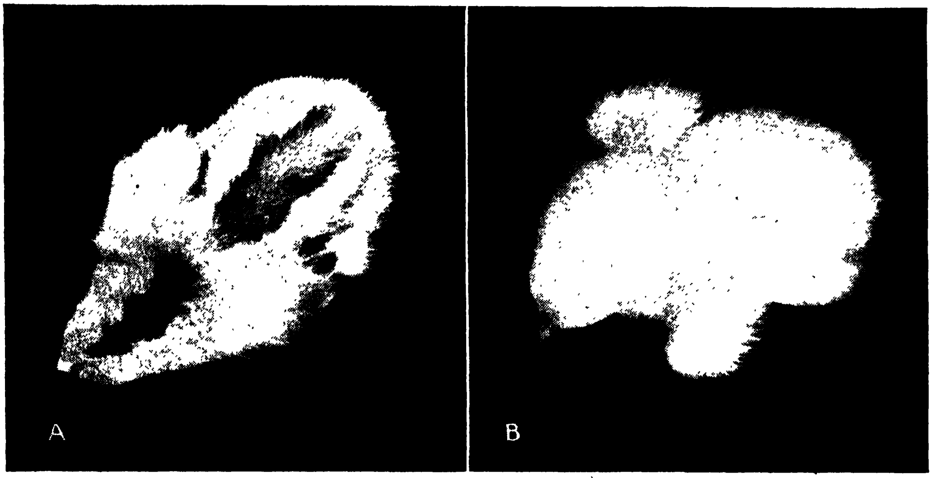

FIG. 23.—The chicks of a Rhode Island Red × White Plymouth Rock cross can be separated according to sex at hatching time by the difference in down color; *A*, The down color in a female chick secured from the sex-linked cross of Rhode Island Red male and White Plymouth Rock female. As an adult this female will be buff to red in color, perhaps with some striping. *B*, The down color in a male chick secured from the sex-linked cross of Rhode Island Red male and White Plymouth Rock female. As an adult this male will have the Columbian pattern as in the Light Brahma and Light Sussex. (*U. S. Dept. Agr.*)

Another kind of sex-linked cross that enables the sex of chicks to be distinguished at hatching time is the "gold" and "silver" cross. The two terms refer to two well-known ground colors of the down of the chicks of several different breeds and varieties. To the gold class belong those breeds and varieties in which the ground color of the down is some shade of buff or golden brown, such as Buff Plymouth Rock and Rhode Island Red. Also belonging to this class are those breeds or varieties in which the adult male is black red in plumage color, such as Brown Leghorn and Golden-Laced Wyandotte. To the silver class belong those breeds and varieties in which the ground color of the down is creamy silver, such as Light Brahma and Columbian Plymouth Rock. The gene for silver is sex-linked, so that in the gold male × silver female cross the female must belong to the silver class.

TABLE 4.—SEX-LINKED CROSSES FOR THE PRODUCTION OF CHICKS THAT CAN BE DISTINGUISHED ACCORDING TO SEX AT HATCHING TIME
(Adapted from Warren, 1930)

Nonbarred males	*Barred females*	*Color of chick*	*Color of adult progeny*
1. Black varieties.......	Barred Plymouth Rock	Females all black on top of body. Beak, shanks, and toes very dark Males black on top of body except white spot on head. Beak, shanks, and toes yellow	Females black. Beak, shanks, and toes very dark Males barred. Beak, shanks and toes yellow
2. Rhode Island Red, Buff Plymouth Rock, Brown Leghorn, and all other black-red color varieties	Barred Plymouth Rock	Same as chicks in No. 1	Same as in No. 1, except females may show red or gold on neck or breast
3. Most white varieties except White Leghorn and White Plymouth Rock	Barred Plymouth Rock	Same as chicks in No. 1	Same as in No. 1
Gold males	*Silver females*	*Color of chick*	*Color of adult progeny*
4. Rhode Island Red....	White Wyandotte. All Columbian pattern varieties. All Silver-Laced and Silver-Penciled varieties	Females buff or red, may show narrow striping Males cream or white, may show narrow striping	Females buff or red, may show some stippling or striping Males Columbian plumage pattern
5. Buff varieties........	Same as in No. 4	Same as in No. 4 except females are usually lighter in color	Same as in No. 4, except females usually buff
6. Brown Leghorn and other black-red color varieties	All Columbian pattern varieties	Same as in No. 4	Same as in No. 4
Rapid-feathering males	*Slow-feathering females*	*Chick wing feathering*	*Adult wing feathering*
7. Leghorn and other Mediterranean breeds	American, Asiatic, and English breeds	Females well-developed wing feather Males none or very short wing feathers	No differences between sexes in adult wing feathering

Still another kind of cross can be made that permits the separation, at hatching time, of the chicks according to sex. It is well known that purebred Leghorn chicks acquire their first feathers, especially wing and tail feathers, sooner than purebred chicks of such breeds as Brahma, Plymouth Rocks, Rhode Island Reds, and Orpingtons. The relatively slower feathering characteristic of the Asiatic, American, and English breeds is sex-linked, so that if the females of these breeds are mated with Leghorn males the chicks can be assorted as to sex at hatching time by the rate of the growth of the wing feathers. The male chicks show no wing-feather development, whereas the female chicks show wing-feather development.

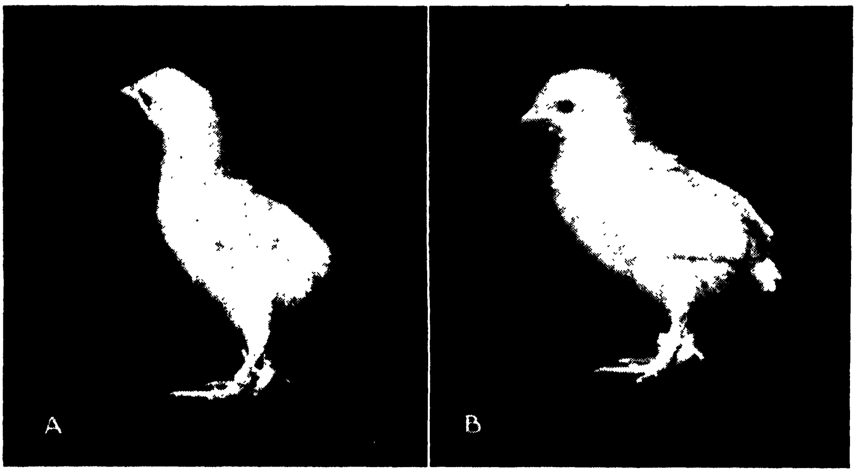

FIG. 24.—Slow feathering is dominant to rapid feathering and is sex-linked, so that when a White Leghorn male is mated to a Jersey Black Giant female the sons are slow-feathering, as shown in *A*, and the daughters are rapid-feathering, as shown in *B*. (*U. S. Dept. Agr.*)

During recent years certain breeders have developed purebred strains of Rhode Island Reds and White Leghorns which carry the sex-linked slow rate of feathering, thus making it possible to separate the sexes at hatching time. The same thing should be possible with any breed or variety.

Sexual dimorphism in down color of Rhode Island Red chicks has been demonstrated. In the chicks of some flocks it was found that approximately 85 per cent of the females had some black down, which varied in extent from a slight ticking of black in the down at the base of the head to black striping on the top of the head and along the back. It was also found that approximately 80 per cent of the males were entirely free of black down.

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CHAPTER III

BREEDING PRINCIPLES

The knowledge gained during recent years concerning the mechanism by which various characters that birds possess are inherited from generation to generation has resulted in a shift in the emphasis placed on selection and breeding methods. In the early days of poultry breeding in the United States practically all of the emphasis in the selection of breeding stock was placed upon the external appearance of the birds. Birds possessing fine form and excelling in color markings or plumage pattern were selected to perpetuate their kind.

Later came the urge to select breeding stock for increased egg production because of the increasing importance of that branch of the poultry industry. The practice of selecting breeding stock on the basis of body shape became quite prevalent because of the mistaken notion that egg-laying ability was related to the body shape of the female. When this notion was demonstrated to be untenable, the theory was advanced by some that the number of eggs a bird laid in one year was an infallible criterion of her ability to transmit to her daughters their ability to lay approximately the same number of eggs. Recent years, however, have shown this theory to be of very limited value, so that poultry breeders have become intensely interested in the development of a sounder basis for the selection of their breeding stock.

The breeding worth of a male and a female is demonstrated very largely by the kind of progeny they produce. This is true regardless of the character involved. A male and a female each with a fine shape of comb may produce progeny having a poor shape of comb. A male whose dam had a high record of egg production mated to a female with a high egg record frequently produces daughters that lay poorly. The results secured from a given mating are determined by the genetic constitution of the birds mated rather than by their physical appearance. What a chicken looks like is an outward expression of the functioning of the germ plasm of its parents. It is not the "outside" so much as the "inside" of the chicken that counts in determining its breeding worth.

Chickens are bred primarily for egg and meat production, although some poultry breeders are more interested in producing birds of a particular type or with a particular plumage pattern. Whatever may be the object, marked progress can be achieved only when the poultry

breeder has an intelligent understanding of the principles involved in the inheritance of the different characters that fowls possess.

Inheritance is transmission from parent to offspring. The characters are not transmitted bodily, however, as shown in the previous chapter, but it is the ability to develop such characters as single comb, barred plumage, and egg production that is inherited. In his poultry breeding operations, the poultry breeder must always keep in mind certain fundamental principles that inescapably apply regardless of the character being developed. A mechanism of inheritance is involved, the results secured from any particular mating depending upon the kind of genes which each of the parents possesses, the genes being the determiners of the hereditary characters.

The Principle of Dominance.—In the discussion in the previous chapter on the sex-linked inheritance of barring, it was observed that barring is dominant to nonbarring. Dominance is also to be observed in the inheritance of characters that are produced by the genes borne on the autosomes. For instance, when a Black Rose-comb Bantam of either sex is mated with a White Rose-comb Bantam of the opposite sex all of the offspring are black. In this particular cross the gene for black plumage is said to be dominant to the gene for white plumage, or, more briefly, black is dominant to white. White is said to be recessive to black.

MENDELIAN INHERITANCE

The manner in which the characters black and white are inherited in a cross between Black Rose-comb and White Rose-comb Bantams serves to illustrate the mechanism involved in the inheritance of most pairs of characters. The parental generation, meaning the parents used in the original cross, is designated by the symbol P_1. The offspring, or progeny, secured from the original cross is known as the first filial generation and is designated by the symbol F_1. When members of the first filial generation are mated among themselves they produce the second filial generation, which is designated by the symbol F_2. Briefly then, P_1 produces F_1, and F_1 produces F_2.

Homozygous and Heterozygous Individuals.—The genes for black in the Black Rose-comb Bantam are in pairs, one of each pair being borne in one of a pair of autosomes. Likewise, the genes for white in the White Rose-comb Bantam are borne in the autosomes, and the genes are in pairs. Since the black parent has two genes for black, the bird is said to be homozygous for black, which simply means that its zygote contains two similar genes for the character that is expressed. Since the white parent has two genes for white, the bird is said to be homozygous for white, which simply means that its zygote contains two similar genes for the character that is expressed.

When the black parent is crossed with the white parent, the birds of the F_1 generation each inherit one of the genes for black from the black parent and one of the genes for white from the white parent. The birds of the F_1 generation are all black because black in this cross is dominant to white, but they are heterozygous for black and for white because each of their zygotes contain one gene for black and one gene for white, the term heterozygous simply meaning zygotes that contain dissimilar genes.

The Principle of Segregation.—When the birds of the F_1 generation are mated among themselves they produce an F_2 generation in the proportion of 3 blacks to 1 white. The genes for two contrasting characters, black and white, which are brought together in F_1 segregate in definite proportions in F_2.

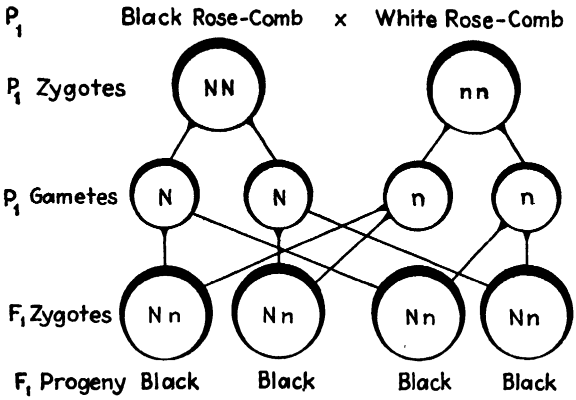


FIG. 25.—The parental zygotes give rise to the parental gametes and the gametes unite in pairs to form the first hybrid generation or F_1 zygotes. The zygotes give rise to the F_1 progeny, which are called "hybrids" in respect to the inheritance of the particular character concerned, and since black, N, is dominant to white, n, all of the progeny are black.

Although the F_2 generation is comprised of 3 blacks to 1 white, the blacks differ among themselves in respect to the results they produce when they are bred. Among every 3 blacks 1 is homozygous whereas the other 2 are heterozygous for black. The F_2 white birds are homozygous recessives and, therefore, produce nothing but white progeny when bred among themselves. The F_2 ratio of 3 blacks to 1 white is really a ratio of 1 homozygous for black to 2 heterozygous for black and for white to 1 homozygous for white. It should be observed that the F_2 homozygous black is just as pure for black as are its black grandparent, although the parents of the F_2 blacks had a gene for white as well as for black. Likewise, the F_2 homozygous white is just as pure for white as its white grandparent in spite of the fact that the F_2 white bird's parents were black.

The demonstration of the segregation of the genes in the F_2 generation is the first of two basic principles of Mendelian inheritance, which simply means the theory of inheritance first propounded by Mendel.

The Principle of Independent Assortment.—The second of the two basic principles of Mendelian inheritance is that of the independent assortment of the genes. This principle is illustrated clearly in the inheritance of two pairs of characters, which is precisely the same in principle as the inheritance of one pair of characters, *e.g.*, black plumage and white plumage, which has just been discussed.

When two pairs of characters are involved, the birds of the F_1 generation are able to produce four kinds of gametes instead of only two, as in the inheritance of one pair of characters. Since four kinds of gametes are produced by each sex, the possibilities for the segregation and recombination of the genes is four times as great as in the case when only two kinds of gametes are formed.

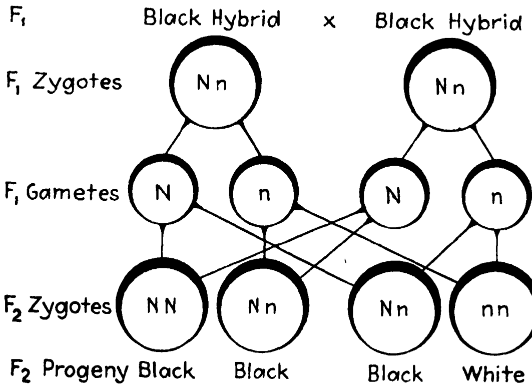


FIG. 26.—The F_1 zygotes give rise to the F_1 gametes, and these gametes unite in pairs to form the F_2 zygotes, which give rise to the F_2 progeny. The color of the progeny is in the proportion of three blacks to one white. It is observed that among the blacks one is homozygous and two are heterozygous for color. The homozygous black and the homozygous white are the same kind of birds as the original parents (see P zygotes in Fig. 25).

A cross between a Single-comb Black Langshan of either sex and a Rose-comb White Minorca of the opposite sex produces an F_1 generation of rose-comb black birds because rose comb is dominant to single comb and black is dominant to white, in this cross. When birds of the F_1 generation are mated among themselves they produce an F_2 generation of four kinds of birds, as far as comb type and plumage color are concerned, in the following proportions: 9 rose-comb blacks, 3 rose-comb whites, 3 single-comb blacks, 1 single-comb white. Two new kinds of birds appear in the F_2 generation, the rose-comb blacks and the single-comb white. It should be observed at this time that the same kind of F_2 generation, as far as comb type and plumage color are concerned, would have resulted from an original cross of Rose-comb Black Leghorn of either sex and Single-comb White Orpington of the opposite sex. In other words, the particular combination in which the pairs of genes for the two

characters are brought into a cross makes no difference at all in the manner in which they segregate and recombine to produce the F_2 generation.

Out of every 16 birds in the F_2 generation there are 12 rose combs to 4 single combs, a 3:1 ratio, and there are 12 blacks to 4 whites, a 3:1 ratio. Of the 12 rose combs there are 9 blacks to 3 whites, a 3:1 ratio. Of the 4 single combs there are 3 blacks to 1 white, a 3:1 ratio. Of the 12 blacks there are 9 rose combs to 3 single combs, a 3:1 ratio. Of the 4 whites there are 3 rose combs to 1 single comb, a 3:1 ratio.

Complementary Genes.—Sometimes certain modifications of the 9:3:3:1 ratio arise as the result of different genes' producing a like effect or as the result of two different genes having a complementary effect on each other when brought together in the original cross. White Dorkings mated to White Silkies produce an F_1 generation of colored birds, and the F_2 generation is composed of birds in the proportion of 9 colored to 7 white. This is a 9:3:3:1 ratio in which the last three groups of birds cannot be distinguished from each other. Lack of space prevents further consideration of other modifications of the 9:3:3:1 ratio.

Modifying Genes.—Several genes may be the determiners of a single character, one gene being primarily responsible for the development of the character, while the other genes affect the degree of development or otherwise modify the expression of the principal gene; such genes are called modifying genes.

Linked Genes.—Certain cases illustrating the fact that segregation and independent assortment of some genes do not take place are those in which certain characters possessed by a bird used in an original cross tend to remain associated with each other in the F_2 generation, owing to the fact that the genes giving rise to these characters are not only on the same chromosome but are linked together in the chromosome. The phenomenon is known as linkage, and research studies have shown that the genes for single comb and for the Creeper condition exhibit linkage, as well as the genes for crest, frizzling, and dominant white. In so far as available evidence is concerned, linkage is of relatively little importance to poultry breeders, but there is a possibility that linkage may be shown between genes for certain structural and genes for certain physiological characters, such as egg production. The linkage of genes should not be confused with sex-linked inheritance. A corollary phenomenon of linkage is that of crossing over, which sometimes takes place as the result of an interchange of parts of the same pair of chromosomes.

Lethal Genes.—One of the surprising things revealed in recent studies on inheritance is that there are genes that when in a homozygous condition kill the chick embryo. One illustration will suffice to show how the presence of a lethal gene disturbs the ratio of 3:1 expected in the F_2 generation. The Creeper chicken, with its very short legs, is due to the

presence of a dominant gene for short legs. An F_2 generation secured from an original cross between Creepers and normal chickens consists of the proportion of 2 Creepers to 1 normal instead of 3 Creepers to 1 normal. The reason for this abnormal situation is that when the gene for the Creeper character is in a homozygous condition the embryo never hatches. The significance of lethal genes on hatchability is discussed in a later section.

Mutations.—Occasionally, a new character appears unexpectedly in one generation and is subsequently found to be inherited. Such a sudden variation that is inherited is called a "mutation" and is due to a change in one or more genes.

Genotype and Phenotype.—The term "genotype" refers to the genetic constitution of a bird, whereas "phenotype" refers to a bird that is shown to possess certain characters. Birds belonging to the same phenotype may belong to different genotypes. For instance, the F_2 generation of a cross between a Black Rose-comb and a White Rose-comb Bantam is comprised of the proportion of 3 blacks to 1 white, and among every three blacks one is homozygous for black whereas the other two are heterozygous for black. The three blacks belong to the same phenotype, but the homozygous black belongs to one genotype, and the heterozygous blacks belong to another genotype.

Dominant and Recessive Characters.—Most of the characters whose inheritance has been determined are listed in the table on page 68.

Most of the characters listed in Table 5 which have been found to be inherited in typical Mendelian manner are for the most part simple characters. The listing of the known dominant and recessive characters is a matter of convenience to the readers of this book and is impressive from the standpoint of showing the progress achieved to date. The inheritance of some of the characters listed is somewhat more complicated, however, than would appear from the table, but lack of space prevents other than a very brief discussion of a few of the characters studied.

The white plumage of the White Leghorn is almost completely dominant to colored plumage so that when a White Leghorn of either sex is mated to a colored bird of the opposite sex the adult progeny have white plumage except that some individuals may have flecks of black in a few of the feathers; if the colored male is a Rhode Island Red, the male progeny usually have red on the shoulders, and some of the female progeny may have red on the breasts. The dominance of the white plumage of the White Leghorn is due to the presence of a gene that prevents color from being expressed; otherwise the bird would be barred, for it also carries genes for barring, color, and the extension of black pigment.

The two kinds of recessive whites differ in the complementary genes that are necessary for the development of color, one kind of recessive

TABLE 5.—DOMINANT AND RECESSIVE CHARACTERS IN CHICKENS

Characteristic	Dominant or recessive	Autosomal or sex-linked
White plumage	In White Leghorns, almost completely dominant to color	Autosomal
White plumage	In White Dorkings, Langshans, Minorcas, Plymouth Rocks, Wyandottes, recessive to color	Autosomal
White plumage	In some strains of White Rose-comb Bantams and White Silkies, recessive to color	Autosomal
Red-splashed white plumage	Recessive to solid color and to color pattern	Autosomal
Albino	Recessive to normal	Autosomal
Black plumage	Dominant to recessive white	Autosomal
Blue plumage	Due to heterozygous condition of color genes	Autosomal
Buff plumage	A multiple gene character dominant to recessive white, recessive to black, and recessive to "silver"	Autosomal, Autosomal, Sex-linked
Silver plumage	"Silver" in Columbian, Silver Laced and Silver Penciled varieties dominant to "gold" in Red, Buff, Golden Laced and Golden Penciled varieties	Sex-linked
Barred plumage	In Plymouth Rocks, dominant to nonbarring	Sex-linked
Barred plumage	In Campines, dominant to nonbarring	Autosomal
White skin and shank color	Dominant to yellow skin and shank color	Autosomal
Dark skin and shank color	Recessive to nondark skin and shank color	Sex-linked
Rose comb	Dominant to single comb	Autosomal
Pea comb	Dominant to single comb	Autosomal
Walnut comb	Dominant to rose, pea, and single	Autosomal
Side sprigs	Dominant to normal comb	Autosomal
Crest	Dominant to absence of crest	Autosomal
Muff and beard	Dominant to absence of muff and beard	Autosomal
Naked neck	Dominant to normal neck feathering	Autosomal
Feathered shanks	Dominant to nonfeathered shanks	Autosomal
Vulture hock	Recessive to normal hock	Autosomal
Long tail	Incompletely dominant to normal tail	Autosomal
Hen feathering	Dominant to normal feathering	Autosomal
Frizzle plumage	Incompletely dominant to normal plumage	Autosomal
Silkie plumage	Recessive to normal plumage	Autosomal
"Frayed" feathers	Recessive to normal feather development	Autosomal
Close feathering	Dominant to loose feathering	Autosomal
Slow feathering	Dominant to rapid feathering	Sex-linked
Flightless	Dominant to normal wing	Autosomal
Rumplessness	Dominant to normal condition	Autosomal
Crooked neck	Recessive to normal neck	Autosomal
Dwarfism	Recessive to normal	Autosomal
Creeper condition	Dominant to normal condition, lethal when homozygous	Autosomal
An embryo lethal	Recessive to normal embryo development, lethal when homozygous	Autosomal
"Sticky" embryos	Recessive to normal, lethal when homozygous	Autosomal
Deformed upper mandible	Recessive to normal mandible, lethal when homozygous	Autosomal
Hereditary blindness	Recessive to normal sight	Autosomal
Parietal baldness	Dominant to normal	Autosomal
Congenital blindness	Dominant to normal	Autosomal
Congenital loco	Dominant to normal	Autosomal
Congenital palsy	Dominant to normal	Autosomal
Polydactyl	Dominant to four-toed condition	Autosomal
Early sexual maturity	Dominant to late sexual maturity	Autosomal and Sex-linked
Broodiness	Dominant to nonbroodiness	Autosomal and Sex-linked

white having one of the complementary genes, the other having the other complementary gene. This explains why the cross of White Dorking × White Silkie, mentioned previously, produces colored progeny. It should be noted that the White Plymouth Rock carries the gene for barring, color, and the extension of black pigment, but it is a white bird because it lacks one of the complementary genes necessary for the development of color. Some of the white recessives carry the "silver" gene.

The blue plumage of the Blue Andalusian is due to the presence of a gene that partially inhibits the development or expression of black pigment. Blue Andalusians are heterozygous for the gene; splashed white Andalusians are homozygous for the gene; black Andalusians are homozygous for the gene recessive to the inhibitor.

Barring in Barred Plymouth Rocks is due to a sex-linked gene, as explained in the previous chapter, which restricts the black pigment in the plumage to bars. The white bars, which alternate with the black ones, are due to the presence of the gene for silver, which is also sex-linked. The Barred Plymouth Rock male is, of course, homozygous for both genes, whereas the female is heterozygous for both genes. The gene for barring apparently has a cumulative effect because the white bars in the male tend to be approximately twice as wide as the black bars. But since the standard adopted for the Barred Plymouth male requires that the white and black bars be of approximately equal width, it is obvious that in the standard female the black bars will tend to be somewhat wider than the white bars.

Although the mode of inheritance of over 40 characters has been determined, a great deal of work has been carried on with other characters, and from time to time the dominance and recessiveness of some of them will undoubtedly be established. With some characters, however, progress in determining their Mendelian inheritance will probably be slow because of the fact that there are in each case many genes involved and there are in addition such complicating factors as the influence of environment, hormones, and management practices on the expression of the character whose inheritance is being studied. The hatchability of eggs, the growth of chicks, the viability or livability of chicks, resistance to disease, egg production, and flesh production are characters of such fundamental importance that knowledge concerning methods of controlling their inheritance should be of vital concern to poultry breeders.

The six characters of fundamental importance just mentioned are known as physiological characters because numerous vital processes that take place within the body of the chicken are involved in their development. That they are inherited there seems to be no question, but the genetic evidence to date indicates that most of the hereditary variations that exist with respect to each of the characters are caused by a large

number of genes, each of which, for the most part, probably exercises a relatively small effect.

Moreover, environment frequently plays an important part in the full development of these characters; in fact, the genes are sometimes unable to develop the characters unless a suitable environment prevails. Two illustrations will serve to emphasize the relationship between heredity and environment in the development of physiological characters: (1) Although the genes for high hatchability may be present, hatching results may be very disappointing owing to faulty methods of incubation; (2) the genes for high egg production may be present, but egg production may be very low as a result of an improperly balanced diet or poor housing conditions. Rarely do ideal conditions of environment prevail whereby the genes are allowed to give full expression to their potentialities.

Then, again, research work has demonstrated that certain hormones, the secretions of endocrine glands, have a pronounced effect upon the physiological processes of the body. For instance, certain hormones have a direct effect on body metabolism, growth, sexual maturity, broodiness, egg formation, and egg production.

Although the mode of inheritance of these economically important physiological characters has not been determined, the results of various lines of investigational work have been very fruitful in indicating numerous steps that may be taken to bring their inheritance under control. Before discussing very briefly the results of studies on the inheritance of the various physiological characters, mention should be made of certain problems pertaining to fertility, which in one sense constitutes the first stage in reproduction.

THE PROBLEM OF FERTILITY

The bulk of the evidence from studies on fertility indicate that it is not inherited, although it is well known that fertility may be much better in one flock or strain than another. Cases of sterility in both males and females have been reported, due for the most part to a diseased condition of the reproductive organs or to a pathological condition of the reproductive cells. Practically no inheritance studies have been conducted on sterility.

THE INHERITANCE OF HATCHABILITY

By the term "hatchability" is meant the ratio of the number of chicks that hatch to a given number of fertile eggs, when presumably ideal conditions of incubation prevail. If a hen has 14 eggs that hatch out of 20 fertile eggs set, she is said to have a hatchability of 70 per cent. The fact that hatchability is a complex character determined by a con-

siderable number of genes is indicated by the results of various lines of experimental work.

Evidence indicating that hatchability is inherited is given in Table 6, which gives the hatchability of the daughters of Rhode Island Red and White Leghorn dams, the dams of each breed being divided into two classes. The two Rhode Island Red classes of dams included those having a hatchability of 68 per cent or better and those having a hatchability of less than 68 per cent; the White Leghorn dams were classified according to whether the hatchability was above or below 74 per cent. In the case of each breed the same males were mated to several dams in both classes, and similar males were also mated to daughters from both classes of dams, so that the influence of the males on hatchability was not a factor.

TABLE 6.—THE HATCHABILITY OF RHODE ISLAND RED AND WHITE LEGHORN DAMS AND THEIR DAUGHTERS CLASSIFIED ACCORDING TO THE MEAN PER CENT HATCHABILITY OF THE DAMS
(Jull, 1930)

Breed	Number of dams	Mean per cent dams' hatchability	Number of daughters	Mean per cent daughters' hatchability
Rhode Island Red	51	80.6	105	75.1
	23	59.9	43	66.4
White Leghorn	36	81.2	62	63.4
	24	64.4	43	52.3

The data in Table 7 show that hens having a relatively high hatchability as yearlings tend to have a higher third-year hatchability than

TABLE 7.—THE SECOND- AND THIRD-YEAR HATCHABILITY OF SINGLE-COMB WHITE LEGHORNS CLASSIFIED ACCORDING TO THEIR SECOND-YEAR HATCHABILITY
(Hyre and Hall, 1932)

Group	Second-year hatchability			
	Above 50 per cent		Below 50 per cent	
	Mean per cent hatchability		Mean per cent hatchability	
	2d year	3d year	2d year	3d year
I	72.5	57.5	32.9	40.9
II	71.8	58.2	31.9	41.2
III	72.3	58.9	35.1	54.8

hens having a relatively low hatchability as yearlings. Single-comb White Leghorns, first used as breeders in their yearling year, were divided into two classes depending upon whether their yearling-year hatchability was above or below 50 per cent, and then the mean hatchability of each class was determined for the third year.

The fact that the third-year mean per cent hatchability of each group whose second-year hatchability was below 50 per cent was higher than the second-year mean per cent hatchability was probably because in their second year these birds or their eggs suffered environmental handicaps which prevented the complete expression of hatchability potentialities. This is but one illustration of the difficulties involved in studies on the inheritance of a physiological character like the hatchability of eggs.

Effects of Inbreeding on Hatchability.—The closest form of inbreeding is the mating of brother to sister, and the next closest forms are father to daughter and son to dam. Rarely is such close inbreeding practiced by poultry breeders, but since in many flocks some degree of inbreeding is practiced, the results secured from experimental matings are quite illuminating.

In Table 8 are given data on the hatchability secured from father-daughter outbred, father-daughter inbred, and control matings. The first two matings are two forms of inbreeding. For the first form of inbreeding a cockerel was mated to unrelated pullets, and the next year the same male was mated to his female progeny secured from the first mating. This constitutes the father-daughter outbred mating. For the second form of inbreeding a family from an original outbred mating was selected, a cockerel of this family was mated to his sisters, and the next year he was mated to his female progeny secured from the brother-sister mating. This constitutes the father-daughter inbred mating.

TABLE 8.—PER CENT HATCHABILITY OF FATHER-DAUGHTER OUTBRED, FATHER-DAUGHTER INBRED, AND CONTROL MATINGS
(British Ministry of Agriculture and Fisheries, 1934)

Breed	Father-daughter outbred and control matings			Father-daughter inbred and control matings		
	Period	F.D.O.	Control	Period	F. D. I.	Control
W. Wyandotte....	1927 to 1931	55.2	64.6	1927 to 1931	44.1	62.7
R. I. Red.........	1927 to 1928	48.5	52.9	1927 to 1929	51.1	63.6
W. Leghorn.......	1927 to 1928	48.9	81.4	1927 to 1929	52.0	74.8

The data in Table 8 show that in every case the hatchability in both forms of inbreeding was lower than that of the control matings, in some cases the difference being very pronounced.

Hatchability often decreases as the intensity of inbreeding increases. The coefficient of inbreeding is a measure of the intensity of inbreeding and is expressed in terms of a percentage. The coefficient of inbreeding of a half-brother-sister mating is 12.50; of a full-brother-sister mating, 25.00; and of three generations of brother-sister matings, 50.00. Where less intense inbreeding is practiced the coefficient of inbreeding, of course,

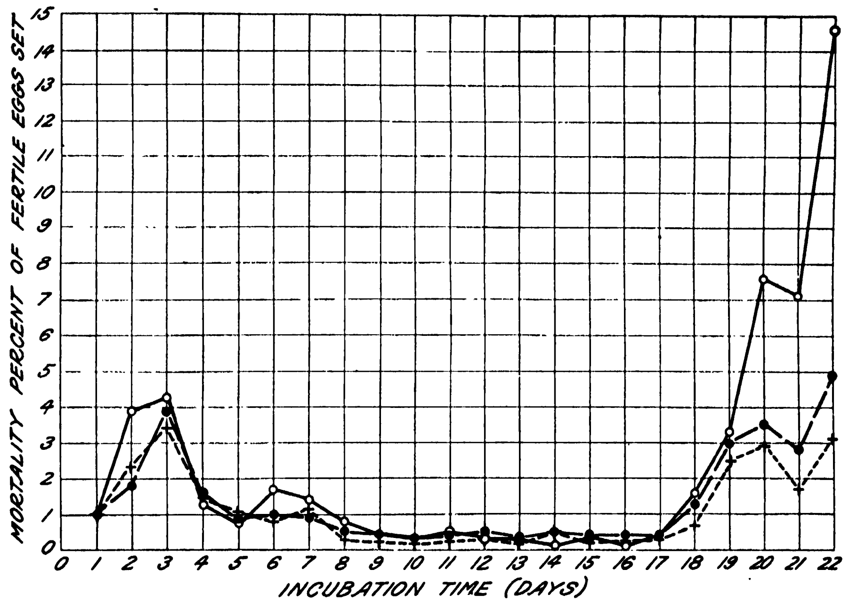


FIG. 27.—Embryonic mortality in eggs from inbred Single-comb White Leghorns, O; unweighted averages for pure breeds, ●; and unweighted averages for crosses between breeds, X. (*Byerly, Knox, and Jull,* 1934.)

is lower. The data in Table 9 show that in three different breeds hatchability decreased as the coefficient of inbreeding increased.

TABLE 9.—HATCHABILITY IN RELATION TO COEFFICIENTS OF INBREEDING
(Jull, 1929; Warren, 1934)

Coefficient of inbreeding	Per cent hatchability		W. Leghorns		R. I. Reds	
	B. P. Rocks	W. Leghorns	Range in coefficient of inbreeding	Per cent hatchability	Range in coefficient of inbreeding	Per cent hatchability
12.50	47.3	58.4				
25.00	40.1	56.6	0 to 10	71.9	1 to 10	56.0
37.50	21.0	52.0	11 to 20	66.1	11 to 40	54.0
50.00	....	43.4	21 to 50	61.6		

The deleterious effects of inbreeding on hatchability are shown to be due largely to increased embryo mortality during the first four and especially the last three days of incubation, as illustrated in Fig. 27.

The hatchability results secured from practically all experiments on inbreeding have been in general accord with those given in the two preceding tables. For the most part these experiments were conducted for the purpose of determining the effects of inbreeding on a number of characters, and no particular emphasis was placed on the selection of breeding stock for high hatchability. The results of an experiment on inbreeding in which in the selection of breeding stock used each year special emphasis was placed on hatchability demonstrate that it is possible to maintain reasonably high hatchability even when relatively intense inbreeding is

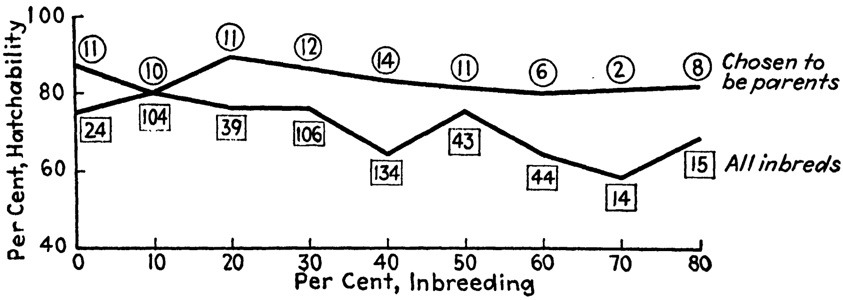


FIG. 28.—Showing the trend in the average per cent of fertile eggs hatched for all inbreds and for those inbreds chosen to be parents, together with the number of birds in each group. (*Waters and Lambert*, 1936.)

practiced. The selection of the progeny to be used as breeders was based on the hatchability of the dam and sire, and the results of this experiment are given in Fig. 28.

Effects of Crossbreeding on Hatchability.—Crossbreeding consists of the mating of males of one breed to the females of another breed. The data on the effects of crossbreeding on hatchability are rather limited, but such data as are available show rather pronounced effects. In practically all cases, however, including those with too limited data to report here, the results are in general agreement: crossbreeding tends to increase hatchability. The data in Table 10 bear out this general conclusion.

TABLE 10.—THE EFFECTS OF CROSSBREEDING ON HATCHABILITY
(Funk, 1934)

Kind of Mating	Per Cent Hatchability
B. P. Rock males × B. P. Rock females	57.0
R. I. Red males × same B. P. Rock females	74.0
W. Leghorn males × W. Leghorn females	70.6
W. P. Rock males × same W. Leghorn females	80.1

Similar results are often secured when rather closely inbred strains of the same breed are crossed. The results given in Table 11 were secured from four pens of White Leghorns which had been inbred by brother-sister matings for three successive generations and then the pens were intercrossed. The third-year inbred male from pen 1 was mated with the third-year inbred females from pen 2, the third-year inbred male from pen 2 was mated with the third-year inbred females from pen 1, and in similar manner the third-year inbred males from pens 3 and 4 were exchanged.

TABLE 11.—THE EFFECTS OF CROSSING INBRED STRAINS OF WHITE LEGHORNS ON HATCHABILITY
(Jull, 1933)

Strain	Per cent hatchability			
	Pen 1	Pen 2	Pen 3	Pen 4
Third-year inbred mating	55.7	49.9	55.8	33.7
Inbred matings intercrossed	57.4	57.5	62.7	50.9

The increased hatchability usually obtained from crossbreeding and from the intercrossing of inbred strains of a breed is due largely to lower embryo mortality during incubation, especially during the first 4 and the last 3 days of the incubation period, as shown in Fig. 27.

The possibility of increasing hatchability through crossbreeding is limited, however, inasmuch as it has been determined that when two breeds each noted for high hatchability are crossed, hatchability is not likely to be increased. On the other hand, the crossing of two breeds each noted for low hatchability is likely to result in materially increased hatchability.

Genes Having a Lethal Effect.—Research work on hatchability conducted during recent years has demonstrated that when certain matings are made, a certain gene from the sire and a similar gene from the dam brought together in the embryo cause its death. The lethal effect of the genes result from their being in a homozygous condition. One of the best examples of this is illustrated in the case of the results secured in the second filial generation of an original cross between the Creeper and a normal fowl, which has already been discussed. The Creeper character is due to a dominant autosomal gene, and the second filial generation would be expected to consist of 3 Creepers to 1 normal, whereas the ratio secured is always 2 Creepers to 1 normal. The embryos that fail to hatch are those which contain the deleterious gene in a homozygous condition, the Creepers that hatch having the gene in a heterozygous condition, the same as the Creeper parent in the original stock.

Three other genes having a lethal effect when in a homozygous condition have been identified: (1) an embryo lethal gene, (2) a gene giving rise to the development of "sticky" embryos in which the bones are soft and fluids in the egg remain unabsorbed at hatching time, (3) a gene giving rise to a deformed upper mandible. As time goes on probably more genes having a lethal or semilethal effect will be identified.

It should be observed, however, that any lethal gene introduced into a flock will be reduced to relatively infrequent occurrence under normal circumstances.

Many Genes Determine Hatchability.—Hatchability is a complex physiological character which is undoubtedly determined by a very large number of characters. The available evidence indicating that many genes are involved includes: (1) the fact that close inbreeding usually results in decreased hatchability—the closer the inbreeding the greater the decrease—(2) intercrossing highly inbred lines usually results in increased hatchability; (3) crossbreeding usually results in increased hatchability; (4) several genes having a lethal effect have already been identified.

THE INHERITANCE OF VIABILITY

Data on the inheritance of viability in growing chicks and in adult stock are very limited for the simple reason that the environmental conditions under which birds are kept and methods of feeding frequently affect the health of the birds to such an extent that it is impossible to determine whether or not there is natural immunity from or resistance to the organisms of disease.

Two references are sufficient to demonstrate, however, that different strains of birds differ in their inherent ability to resist disease. The first reference has to do with differential mortality among strains of chicks. Chicks reared under identically the same environmental conditions and fed the same diets but secured from different strains of birds entered in the Nebraska flock-testing project in 1935 showed great variation in mortality during the first 4 weeks according to the strain from which the chicks were hatched. In some strains of heavy breeds the mortality during the first 4 weeks was as low as 13 per cent, and in other strains as high as 70 per cent. Among the Leghorn chicks the first 4-week mortality varied from 1 per cent in the chicks of one strain to 31 per cent in the chicks of another strain. The second reference has to do with differential mortality among strains of laying pullets. From an analysis of mortality data in the Suffolk laying trials in England from 1930 to 1935, inclusive, it was observed that among 20 individual poultry breeders 12 of them had birds in which the mortality amounted to only 7 per cent, whereas the 8 others had birds in which the mortality was 20 per cent. It is quite clear

from these two references that certain strains of chicks and certain strains of laying pullets were much more susceptible to disease than others.

During recent years the results of certain lines of investigational work indicate that it is possible to develop, by selection, strains of birds resistant to specific diseases. In one experiment of 10 years' duration carried on at the Illinois Agricultural Experiment Station it has been shown that chicks from certain hens were much more resistant to infection by the causative organism of pullorum disease than were chicks from other hens. Selection was effective in developing strains more resistant than were unselected stock, and the selected strains were consistent in maintaining resistance through successive generations. Resistance was found to be dominant to susceptibility. In another experiment, carried on at the Iowa Agricultural Experiment Station, it was found that four generations of selection, combined with some inbreeding, resulted in a marked increase in resistance to fowl typhoid, multiple genes, some of which exhibited dominance or partial dominance, being involved. The results of two experiments have shown that there is a decided variation in the susceptibility to paralysis exhibited by different strains of birds.

The Effects of Inbreeding and Crossbreeding.—In Table 12 are given data on the percentages of chicks reared up to 16 weeks of age under the same two forms of inbreeding and control matings as discussed in connection with Table 8.

TABLE 12.—PER CENT CHICKS REARED UP TO 16 WEEKS IN FATHER-DAUGHTER OUTBRED, FATHER-DAUGHTER INBRED, AND CONTROL MATINGS
(British Ministry of Agriculture and Fisheries, 1934)

Breed	Father-daughter outbred and control matings			Father-daughter inbred and control matings		
	Period	F. D. O.	Control	Period	F. D. I.	Control
W. Wyandotte.....	1927 to 1931	63.0	78.0	1927 to 1931	65.1	76.4
R. I. Red.........	1927 to 1928	65.9	78.8	1927 to 1929	46.2	73.3
W. Leghorn.......	1927 to 1928	41.4	62.4	1927 to 1929	39.7	64.9

The data in Table 12 show that in every case chick mortality was greater under each form of inbreeding than under the control matings. The effects of inbreeding on the viability of chicks are much the same as the effects of inbreeding on the viability of embryos during incubation. At the same time, it should be possible to develop, by properly controlled selective inbreeding, strains in which the viability would not be excessive.

Crossbreeding, on the other hand, frequently results in lowered mortality among the progeny, as shown in Table 13.

TABLE 13.—PER CENT CHICKS REARED UP TO 3 WEEKS IN WHITE LEGHORN, RHODE ISLAND RED, AND CROSSBRED MATINGS
(Warren, 1930)

Mating	Chicks Reared
W. Leghorn	93.96
R. I. Red	92.97
W. Leghorn male × R. I. Red females	96.91
R. I. Red male × W. Leghorn females	99.94

The viability of chicks from crossbred matings is undoubtedly affected to a considerable extent by the vigor or other qualities of the pure breeds that are crossed. Pure breeds in which the viability of chicks is high could not be expected to give materially higher viability when crossed, whereas pure breeds in which the viability of chicks is comparatively low would be expected to give considerably higher viability when crossed.

THE INHERITANCE OF THE RATE OF GROWTH AND BODY SIZE

Aside from the fact that the males in each breed usually grow faster than the females and that birds belonging to the light-weight breeds, such

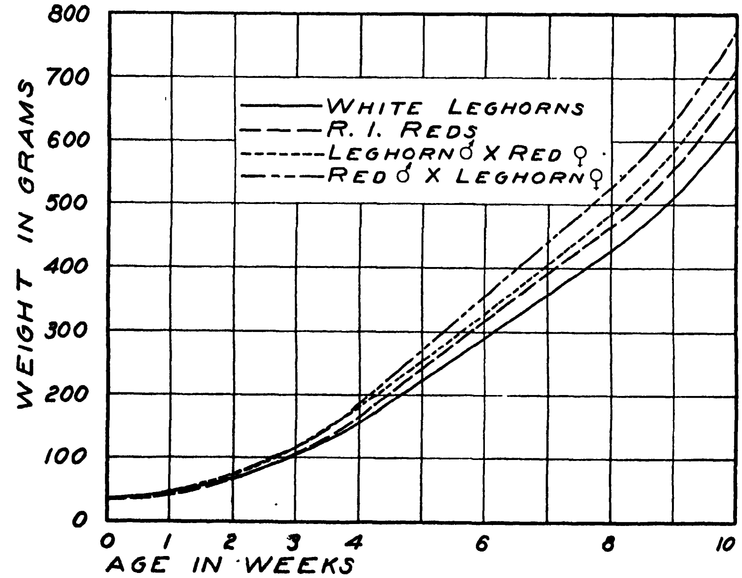


FIG. 29.—Comparison of growth of White Leghorns, Rhode Island Reds, and hybrids resulting from their crossing. (*Warren*, 1930.)

as Leghorns, reach maturity earlier in life than heavy-weight breeds, such as Brahmas, comparatively little evidence has been accumulated on the inheritance of the rate of growth. That there is great variability in the rate of growth among strains of the same breed is a matter of common observation among poultry raisers. It has also been observed that among birds of the same breed or variety those with the narrowest feathers

usually grow at a slower rate than birds with relatively wide feathers. Moreover, it has been found that in Barred Plymouth Rocks and Rhode Island Reds birds with very narrow feathers are apt to be relatively bare of feathers over the back during the first 6 or 8 weeks of the growing period. The problem of determining the mode of inheritance of the rate of growth is so complex, however, that comparatively little progress has been achieved. One of the major difficulties involved is that of maintaining the parents and their progeny under strictly uniform conditions, including environment and methods of feeding.

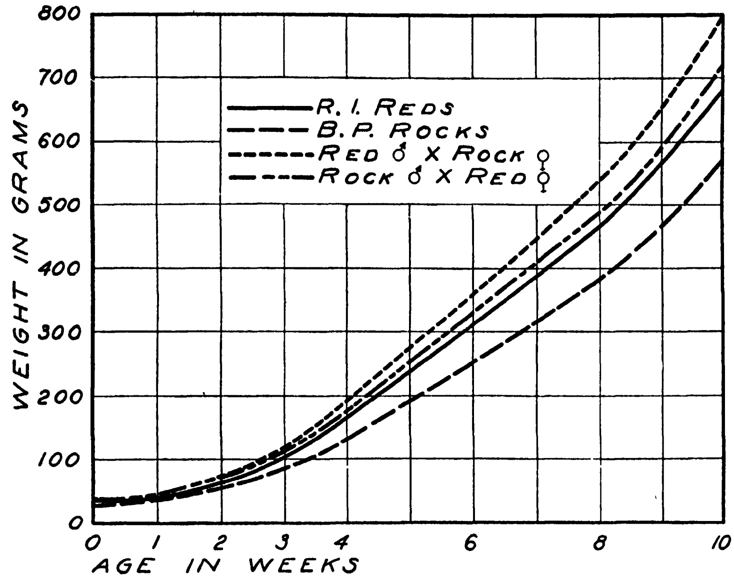


FIG. 30.—Comparison of growth of Rhode Island Reds, Barred Plymouth Rocks, and hybrids resulting from their crossing. (*Warren*, 1930.)

Observations made at the Oklahoma Agricultural Experiment Station led to the conclusion that the rate of growth during the first 8 weeks is a separate entity not necessarily related to adult body size.

Most investigations on the rate of growth have involved the crossing of breeds. For the most part the results secured from these investigations show that the progeny of crossbred matings usually grow faster for the first 10 or 12 weeks than the purebred chicks obtained from the purebred parents that were crossed. The growth curves in Figs. 29 and 30 show the effects of crossbreeding on rate of growth during the first 10 weeks.

The adult body size that is attained is the result of the cumulative effects of the rate of growth and the length of time that growth continues. In experiments conducted at the National Agriculture Research Center, in which the two breeds crossed differed widely in adult body size, it has been found that the adult weight or size of the progeny was slightly below the mid-weight of the two breeds crossed. In experiments in which the

two breeds crossed did not differ widely in adult body size, it has been found that the adult size of the progeny was approximately intermediate between the size of the two breeds crossed. The wide variability in adult body size that usually exists among both males and females of parental breeds that are crossed and the relatively few progeny that are sometimes secured from crosses make it impossible to draw definite conclusions concerning size inheritance except that it is obvious that a large number of genes is involved.

Moreover, it has been determined that body size shows much greater variability than the measurements of the long bones of the body. From studies conducted at the California Agricultural Experiment Station it was concluded that shank length measured on live birds constitutes a valid criterion of heritable differences in body size. The results of studies on the inheritance of bone measurements indicate not only that many genes determine body size in general but also that special or modifying genes affect different parts of the body.

THE INHERITANCE OF EGG PRODUCTION

The fact that many strains of modern breeds lay an average of 180 or more eggs per bird during the first laying year as compared with an average of probably 12 or 15 eggs per bird by the ancestors of modern stocks indicates that egg production is inherited. Too much must not be taken for granted, however, for the simple reason that much of the improvement in egg production that has taken place over a long period of years is due to the results of domestication and better methods of management, including the feeding of better balanced diets. Nevertheless, it has been well established that egg production is inherited, although the mode of inheritance has yet to be determined.

In the case of the wild stocks the females upon laying about 12 or 15 eggs in the spring of the year became broody, egg production ceased, and then in the summer or fall the old birds underwent their first annual molt. Reproduction in the case of practically all wild birds follows the same course of events: the spring lay, the onset of broodiness accompanied by cessation of egg production, the summer or fall molt. It has been demonstrated, however, that by removing eggs from the nest as they are laid, certain species of wild birds can be induced to lay many more eggs than is customary. The increase in the egg production of the domestic fowl has resulted from providing better environmental conditions and by the judicious selection of breeding stock over a long period of time.

Although many strains of modern breeds lay an average of 180 or more eggs in a year, there is still great variability among all of the stocks of any country, for some strains or families may average only 80 or 90 eggs per

bird, while other strains or families may average 200 or more eggs per bird even though all may be kept under the same environmental conditions.

Studies on the inheritance of egg production have been based for the most part on the number of eggs laid from the time that laying began to and including 365 days thereafter, this period denoting what is called the "first laying year." Perhaps, however, the first laying year should embrace the period from the onset of egg production to the time of cessation of egg production preceding the first annual molt. This involves several difficulties, the chief of which is that it is extremely difficult to determine when the first annual molt begins and when it is completed. Moreover, the cessation of egg production does not always precede the annual molt. As a matter of fact, egg production is such a complicated physiological process that any basis upon which its inheritance is studied involves numerous difficulties. On the other hand, the 365-day period from the time that laying begins has been found satisfactory for all practical purposes, and the subsequent discussion on the extensive observations of many investigators is condensed with a view toward presenting as comprehensive a picture as possible of existing knowledge concerning the inheritance of egg production, the most important economic character with which most poultry breeders are concerned.

It has been found that the following four factors are of major importance in determining the number of eggs laid during the first laying year: (1) age at which laying begins, known as "sexual maturity"; (2) rate of laying; (3) broodiness; (4) persistence of production. These four biological factors have each been found to be intimately associated with total first-year egg production. A fifth factor, that of pause in egg production, is believed by some investigators to be a biological factor independent of rate of laying, but it is felt by others to be associated with rate of laying. Each of these five factors is discussed separately.

Sexual Maturity.—It has long since been established that the increase in the level of first-year egg production that has been secured in many flocks is due, to a considerable extent, to the earlier age after hatching that laying begins as compared with poorer producing flocks. When a pullet starts laying she is said to be sexually mature, and recent investigational work has demonstrated that sexual maturity is inherited. In other words, birds that begin laying early in life differ genetically from birds that start late in life.

The data in Table 14 give the results secured in selecting and breeding for early sexual maturity and for late sexual maturity in a flock of Rhode Island Reds. Beginning in 1926 three matings were made of birds that had begun laying at 225 days of age or less, and three other matings were made of birds that had started to lay at 235 days of age or more. The selection and breeding of the early and late sexually maturing birds were

carried on for 6 years, at the end of which time there was a significant difference in the sexual maturity of the early and the late sexually maturing strains.

Table 14.—The Mean Sexual Maturity in Days in an Early-maturing and Late-maturing Strain, Respectively, in Rhode Island Reds Selected and Bred for 6 Years
(Warren, 1934)

Year	Early-maturing strain		Late-maturing strain	
	No. of daughters	Mean sexual maturity, days	No. of daughters	Mean sexual maturity, days
1926	89	269.0	85	276.2
1927	96	230.8	84	249.5
1928	73	221.9	97	247.6
1929	92	211.5	78	252.3
1930	20	216.7	29	249.3
1931	45	222.2	71	269.0

During 1930 and 1931 various matings were made of males from the early-maturing and from the late-maturing strain, respectively, with females belonging to each of the two strains, the results secured indicating that a dominant sex-linked gene and probably several autosomal genes are involved in the inheritance of sexual maturity. Matings were also made between White Leghorns and Rhode Island Reds, the former normally attaining sexual maturity earlier than the latter. The results secured indicated that sex-linked genes are involved in the inheritance of sexual maturity.

These observations confirm in a general way earlier observations made on the inheritance of sexual maturity in Rhode Island Reds at the Massachusetts Agricultural Experiment Station, where 215 days was used as the upper limit for early sexual maturity and 216 days as the lower limit for late sexual maturity.

It should be borne in mind that sexual maturity is not a fixed entity in the case of any one breed or variety. For instance, in studies on the inheritance of sexual maturity involving 225 yearling Rhode Island Reds at the National Agricultural Research Center it has been observed that the mean or average sexual maturity of the 1,689 daughters was 203.8 days. The results secured indicate clearly that the sexual maturity of a dam is not a very reliable criterion of her ability to transmit sexual maturity to her daughters. This means that the phenotypic expression of sexual maturity is not necessarily an expression of the genotypic constitution of the dams. The same situation was found to exist in White

Leghorns at the National Agricultural Research Center, the inheritance studies being based on 2,179 daughters of 284 yearling dams, the period of study covering 7 years, as in the case of Rhode Island Reds. In both studies it was found that full sisters became sexually mature at more nearly the same age than half sisters and less related pullets and that half-sisters became sexually mature at more nearly the same age than less related pullets. The results secured from these two studies indicate that several genes are involved in the inheritance of sexual maturity.

Although it is undoubtedly true that sexual maturity is inherited and that several genes are involved, including at least one sex-linked gene, it is clear from recent research that the cause of differentiation in sexual maturity among birds is accounted for, in part at least, by differences in the functional activity of one or more of the endocrine glands which secrete the hormones, many of which have been shown to have a pronounced effect in regulating various functions of the body. For instance, it has been demonstrated that a hormone secreted by the anterior lobe of the pituitary influences the development of ova and is a factor in determining sexual maturity. It may be, of course, that the functional ability in secreting this hormone at different levels is inherited, but at any rate it is clear that much more work is necessary before the mode of the inheritance of sexual maturity is completely solved.

Rate of Laying.—Nearly all birds lay at a higher rate in the spring of the year than at other times, rate of laying referring to the number of eggs per month or for any given period. It is interesting to observe that for birds in the same latitude in different parts of the world the seasonal curves of egg production are quite similar, as shown in Fig. 31. The reason given for the increase in the rate of laying during the spring months is that the birds respond to the gradual increase from day to day in the amount of daylight or sunlight. It has been demonstrated that the anterior lobe of the pituitary secretes a hormone that provides a stimulus for the development of ova. The activity of the pituitary gland is influenced by the action of light, the bird's eye being sensitive to the intensity of illumination. Under conditions of increasing light intensity more of the hormone is secreted, and this substance circulating in the blood stimulates the ovary to increased production. It should be observed here that the increased egg production that usually follows the artificial lighting of laying houses is due to the increased activation of the pituitary gland by light through the birds' eyes, and as a result of increased egg production the birds consume more feed.

That light exercises a rather pronounced effect on the complicated mechanism of egg laying has been demonstrated by an interesting series of experiments carried on at the Kansas Agricultural Experiment Station. It was first observed that under conditions of normal lighting birds rarely

laid any eggs between 5 P.M. and 6 A.M., suggesting the operation of some regulatory mechanism which prevents the laying of eggs at night. It was

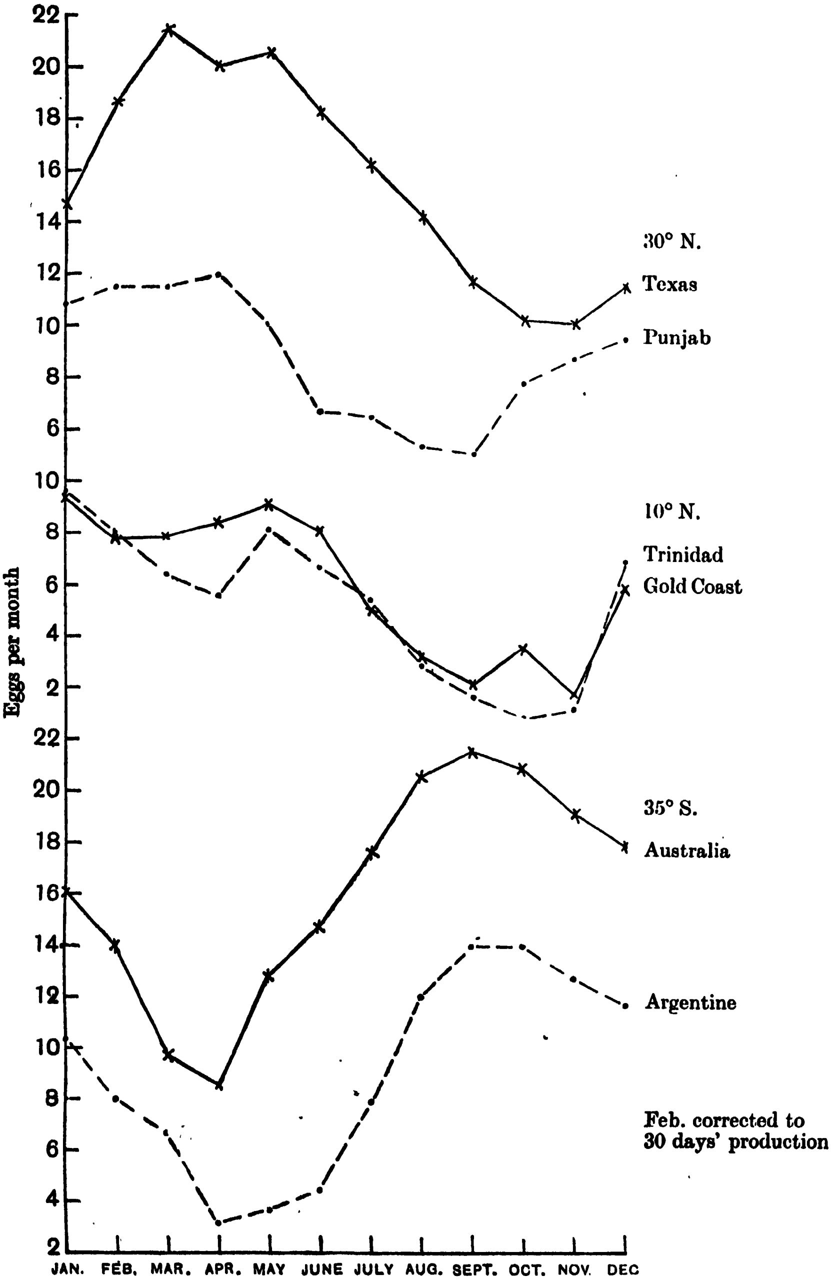


FIG. 31.—Egg-production curves of eastern and western hemispheres at similar latitudes. (*Whetham*, 1933.)

found, however, that when birds that had been under normal lighting conditions were given continuous artificial lighting by using 100-watt

Mazda lamps, with no daylight, the laying period was reversed; *i.e.*, whereas under normal lighting the birds laid in the daytime, after 7 days of continuous artificial lighting they tended to shift their laying more to the night period. Then when the day period was darkened and artificial light was provided at night, the shift in laying during the night period was almost complete, especially after 4 days following the change. When 24 hr. of darkness intervened followed by another shift back to normal daytime lighting and night darkness, the shift to laying in the daytime was almost complete, especially after 3 days following the shift. In other words, under normal daytime light and night darkness hens lay in the daytime; under continuous artificial light they lay throughout the day; under reversed periods of daylight and darkness they lay at night; and under continuous artificial light supplemented by daytime normal light they lay in the daytime.

The results of these and other experiments demonstrate that light exercises a regulatory effect in controlling rate of laying. Ovulation, or the liberation of the yolk from the ovary, is restricted largely to the morning period of the day. The laying of an egg may act as a stimulus to the ovulation of the succeeding yolk, but it is not the only stimulus, for the ovulation of a pullet's first egg must be accounted for as well as ovulation of the first yolk following a period of cessation in laying.

Egg production over a period of time, such as the first-year production, consists of a series of clutches, each clutch consisting of eggs laid on consecutive days. The interruptions that occur between clutches are apparently due to delays in the rate of ovulation. The number of days between clutches is not only determined by a delay in the rate of ovulation but also by the length of time spent by the egg in the uterus of the oviduct. Birds that lay at a high rate have fewer delays in rate of ovulation, and their eggs spend relatively less time in the oviduct than birds that lay at a low rate. In other words, the best layers lay in long clutches with comparatively few intervals, whereas the poorest layers lay in short clutches with numerous short or long intervals between clutches.

In studies on the inheritance of the rate of laying in Rhode Island Reds at the Massachusetts Agricultural Experiment Station it has been demonstrated that clutch size is inherited. In similar studies at the National Agricultural Research Center with White Leghorns and Rhode Island Reds the basis for determining the inheritance of the rate of laying was the percentage production from the date of first egg (sexual maturity) to Mar. 1. The number of eggs laid multiplied by 100 and divided by the number of days involved gives the rate of laying in the case of each bird. It was found that rate of laying is inherited, full sisters laying at more nearly the same rate than half sisters and less related birds, and half sisters laying at more nearly the same rate than less related birds.

Apparently, several genes are involved in the inheritance of rate of laying.

Pauses in Production.—One of the major difficulties in determining the inheritance of pauses in production is to be able properly to classify many of the birds that do not lay for a period of 7 days or more, which is the basis on which birds have been divided into nonpause and pause groups. Any one of the following things can happen to a hen that will cause her to cease laying for a short period: a slight cold, internal parasites, a mild attack of several different kinds of disease, a digestive disturbance, environmental disturbances of one kind or another, and the onset of broodiness. Until more is known concerning the cause of pauses in production it seems justified to regard per cent production from date of first egg to Mar. 1 as a satisfactory measure of the rate of laying.

Broodiness.—It is well known that Mediterranean breeds have much less broodiness than Asiatic, American, and English breeds. Also, strains within a breed may differ significantly concerning the amount of broodiness exhibited. The results of research on the inheritance of broodiness conducted at the Massachusetts and Illinois Agricultural Experiment Stations and Cambridge University have demonstrated that at least one sex-linked gene and probably several autosomal genes are involved.

It seems to be a general phenomenon that when two breeds are crossed, the progeny exhibit a pronounced degree of broodiness, usually considerably in excess of the broodiness shown by either of the parental breeds.

It is very interesting to observe that the pituitary gland of birds that are genetically broody contains larger quantities of a hormone called "prolactin" than the pituitary gland of birds of nonbroody genetic constitution. Also, among birds that are genetically broody, the pituitary of those in broody condition contains more prolactin than when they are not broody. Thus, it is apparent that broodiness is influenced by a complicated physiological mechanism as well as having a genetic basis.

Persistence of Production.—Strains of fowl often differ markedly in the length of time that laying is continued during the summer and fall in the year following that in which the birds were hatched. In fact, families within a strain frequently differ considerably in the length of time that laying is continued toward the close of the first-year production period. Persistence of production is a very desirable characteristic, for it is obvious that the longer that laying continues the greater the first-year record of production.

It has been definitely established that the termination of the first year of laying is intimately associated with the onset of the first annual molt, except that a few birds have been known to continue laying throughout the entire period of molting. The process of molting includes the shedding and renewal of the plumage. In persistent producers molting

takes place much later than in nonpersistent producers, presumably because the activity of the sex glands tends to inhibit the onset of the molting process.

The fact that capons start to molt earlier than normal males and normal males begin molting earlier than persistent-laying females indicates that sexual activity is instrumental in inhibiting the onset of the molting process. The molting process, however, involves a complicated physiological mechanism in which other endocrine glands besides the sex glands play a part. It has been demonstrated that daily implantations of the anterior lobe of the pituitary gland in hens about to undergo the molting process resulted in a retardation of the onset of molting. The removal of the anterior lobe of the pituitary gland is followed by a rapid and extensive molt. It is not to be concluded, however, that the anterior lobe of the pituitary gland in itself inhibits the molt, for its removal invariably results in the degeneration of the sex glands. Moreover, the removal of the sex glands results in an increase in the size of the anterior lobe of the pituitary gland in both males and females. From this it might be expected that the molting process in the capon would be retarded, whereas the onset of molting in capons takes place earlier than in normal males and much earlier than in persistent-laying hens. The reason that capons, without the sex glands but with an enlarged anterior lobe of the pituitary gland, start molting relatively early is because the anterior lobe of the pituitary secretes a hormone that stimulates the thyroid gland, which in turn secretes another hormone that induces molting.

In the case of laying hens the onset of the molt is conditioned by the activity of the ovary and the anterior lobe of the pituitary gland, and when these glands cease to function or function at a lower level, molting is induced through the activation of the thyroid gland. Molting in persistent layers takes place later than in nonpersistent layers as a result of heritable differences in the functioning ability of the ovary and the anterior lobe of the pituitary gland. That persistence of production is inherited there can be no doubt, for by the adoption of a proper system of selection and breeding it is possible to develop in a flock persistent production to a relatively high degree.

THE INHERITANCE OF EGG CHARACTERS

The size, shape, color, and interior quality of eggs are characters that are inherited from generation to generation, although comparatively little research has been undertaken to determine their mode of inheritance.

Egg Size.—Size of egg varies from the very small eggs laid by bantams to the comparatively large ones laid by the larger breeds, but even within a breed or strain egg size varies considerably, there being a tendency for the largest birds in a flock to lay larger eggs than the smallest birds in

a flock. Moreover, the eggs laid by the individual bird frequently vary in size at different stages of the first-year production and at different seasons. In the case of most birds the mean size and the maximum size of egg laid usually differ so that it is difficult to determine the best criterion to use in studies on the inheritance of egg size. Since the size of egg laid is determined largely by the size of yolk secreted and by the size of the oviduct, it is readily understood how complicated is the problem of determining the inheritance of this important physiological character.

Egg Shape.—Practically nothing is known concerning the inheritance of egg shape in spite of the fact that it is well known that practically all of the eggs laid by a hen have the same characteristic shape.

Egg Color.—Egg color is a character on which but little research has been conducted to determine the nature of its inheritance. The crossing of white-egg and brown-egg breeds gives progeny laying tinted eggs, but the shade of tint varies considerably. As a matter of fact, among the brown-egg breeds the eggs laid have several different shades of brown, numerous genes for shell color being involved. The blue shell color of eggs laid by the Araucana fowl from Chile has been found to be dominant to nonblue, a single autosomal gene being responsible.

Interior Quality.—Recent research has demonstrated that certain qualities pertaining to the yolk and the white or albumen of eggs are inherited. Although the factor of major importance affecting yolk color is the kind of diet that birds receive, it has been shown that some birds differ in their ability to transform the pigment from the feed to the yolk. The percentage of thick white in eggs is apparently an inherited characteristic, judging from the observations of three lines of investigational work.

PRINCIPLES INVOLVED IN CONTROLLING INHERITANCE

The ability of the poultry breeder to control the inheritance of a character depends to a considerable extent upon the number of genes that give rise to the character. Where only one gene is concerned, the problem is relatively simple. The Wyandottes have rose combs, but occasionally birds with single combs appear among the progeny secured from a purebred mating of a Wyandotte male and female. Since rose comb is dominant to single comb, there being but a single gene difference, it is obvious that the male and female parents were both heterozygous for rose comb. They each had a gene for rose comb and a gene for single comb but had rose combs because the gene for rose comb is dominant to the gene for single comb. They would produce progeny in the proportion of 3 with rose combs to 1 with single combs. If the poultry breeder wishes to eliminate the single-comb character from his flock, he should discard those that produced the single-comb progeny, and he should also

discard the progeny unless he wished to determine which of the rose-comb progeny was homozygous and which heterozygous for rose combs. The homozygous rose-comb progeny when mated to single-comb birds would produce nothing but rose-comb birds, whereas the heterozygous rose-comb progeny when mated to single-comb birds would produce approximately equal numbers of rose-comb and single-comb birds. It is apparent, therefore, that where only one gene is involved it is a comparatively simple matter for the poultry breeder to control inheritance.

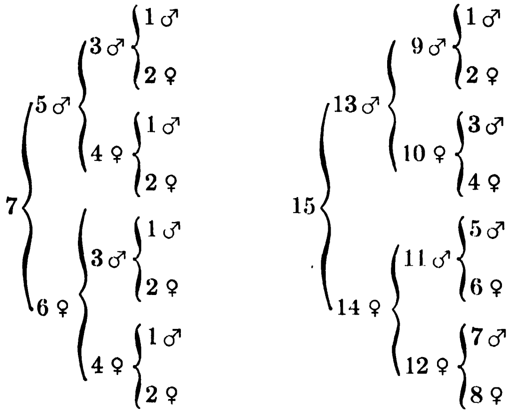
The Possibilities of Selection.—As far as the various physiological characters are concerned, it is safe to say that any two birds will differ genetically to a greater or lesser degree. The problem of the poultry breeder is to be able to identify which of the two is superior in its ability to transmit the desirable genes. It should be kept in mind, however, that selection can do nothing toward creating new genes. Nevertheless, the selection of the best individuals for future breeding purposes makes possible the segregation of desirable genes from each of the parents and the recombination of these desirable genes in the progeny.

One of the inherent difficulties involved in poultry-breeding practice is that the poultry breeder usually considers several different characters simultaneously when making his selections. What he should keep in mind is that the larger the number of characters on which selection is based, the lower the intensity of selection for each of the characters that he is endeavoring to improve by selection. In other words, the more attention paid to unimportant characters the less valuable is the selection for the economically more important characters.

Since the average poultry breeder is desirous of maintaining excellence with respect to each of several characters, such as high hatchability of eggs, good viability in chicks, low mortality in pullets, good egg production, and good egg size, it is obvious that a very large number of genes is involved, inasmuch as there is probably a large number of genes responsible for the development of each of these characters. Very rarely indeed does any individual bird excel in all or even most of the characters; in fact most birds excel in but few characters. It follows, therefore, that the genes that determine these characters are in varying degrees of heterozygosity in practically all birds. The object of the poultry breeder is to produce birds each having as many as possible of the desirable genes. In other words, homozygosity of desirable genes in each bird is the desired goal.

Inbreeding Develops Homozygosity.—Inasmuch as inbreeding is the mating together of closely related individuals, it is obvious that the closer the degree of inbreeding the greater the number of genes in a homozygous condition in the progeny for the simple reason that the more closely related the parents are the greater is the number of similar genes that

are brought together in the matings. The closest form of inbreeding is the mating of a full brother to a full sister, and the next closest form is the mating of a sire to his daughter or a dam to her son. The pedigree of a bird secured from any of these closely inbred matings shows the same ancestor appearing in the pedigree more than once, so that there are fewer different ancestors than in the pedigree of a bird whose parents were unrelated. In the accompanying diagrams, bird 7 is shown to be the product of a mating of a full brother to a full sister for two generations; his great grandsire and great grandam each appear four times in the pedigree, and his grandsire and grandam each appear twice. Individuals having common ancestors tend to have more genes in a homozygous condition than individuals that do not have common ancestors. Bird 15 has no common ancestors in his pedigree.



It should be borne in mind that inbreeding brings together undesirable as well as desirable genes. Since many recessive genes have less desirable effects than dominant genes, inbreeding has the effect of unmasking the presence of these undesirable recessive genes whose effects were masked by the presence of desirable dominant genes. It is when these undesirable recessive genes occur in a homozygous condition that they are able to produce undesirable characters, as has been shown in the preceding pages, especially with such characters as hatchability of eggs and viability of chicks. It should be borne in mind, however, that the results secured from experiments on inbreeding have been secured for the most part from the closest forms of inbreeding. The poultry breeder who has a relatively large number of breeding birds to use each year could safely practice inbreeding to some extent, but he should practice rigid selection of his young and old stock for future breeding purposes.

If undesirable characters appear in inbred birds, it is because undesirable genes existed in the original stock. The appearance of undesirable characters in inbred strains makes it possible for the poultry breeder to

eliminate rather quickly numerous undesirable characters from his flock. Inbreeding, if accompanied by intelligent selection, makes rapid improvement possible because superior families can be readily separated from inferior families.

Crossbreeding Develops Heterozygosity.—Crossbreeding is the mating of birds belonging to different breeds, so that the natural result is to combine many different genes from rather widely separated sources. Since the characters in each of the purebred parents are due, for the most part, to the effects of dominant genes, it is obvious that the progeny of a crossbred mating contains many dominant genes in a heterozygous condition, some of the dominant genes having been received from one purebred parent and some from the other. Many dominant genes produce more favorable effects than do recessive genes, so that progeny produced by crossbreeding is usually superior in many characters over either of the parental breeds crossed. This superiority is said to be due to heterosis or hybrid vigor, the term "hybrid" designating the progeny of a crossbred mating. The results secured from crossbreeding depend to a considerable extent, however, upon the qualities possessed by the parental breeds that are crossed.

Naturally, crossbreeding tends to lower the breeding value of the hybrid progeny by making the progeny more heterozygous and by making selection among the progeny less effective.

A selected list of literature references will be found at the end of the next chapter.

CHAPTER IV

BREEDING PRACTICE

The paramount object of the poultry breeder should be the ability to identify superior-breeding males and females and to mate them in such a way that they will produce the largest possible number of progeny possessing the desirable characters for which the stock is being bred. The ability to identify males and females of superior breeding worth is the first requisite of a successful breeding program. This is just as true in breeding birds for standard-bred excellence as in breeding them for economic qualities. In many flocks far too many birds of inferior breeding worth are used each year because many poultry breeders apparently have never adopted a logical basis on which to select their breeding stock. Mediocrity tends to reproduce itself. The results secured from many matings are largely matters of chance because in too many cases the matings are made by guesswork. How to eliminate some of the guesswork in selecting breeding stock and how to mate males and females of superior breeding worth for the development of superior strains is related in the following pages.

SECURING GOOD FERTILITY

The poultry breeder should always keep in mind that the percentage of fertile eggs secured is the first factor in determining the number of chicks secured in proportion to the eggs set. The proper management of the breeding stock is important in order to secure maximum fertility. The poultry house should be kept dry and clean at all times because filth, dampness, and disease tend to lower fertility.

Extremely cold weather is apt to cause a lowering in fertility, so that special precautions should be taken to keep the house comfortable when the temperature drops suddenly. To avoid the danger of having combs badly frozen, some poultry breeders cut off the combs of the males, this practice being called "dubbing." Sharp scissors may be used to decomb baby chicks, and scissors or tinners' clippers may be used to decomb older birds. The operation should be performed only on a warm day; otherwise excessive bleeding may occur. After the comb has been amputated, a clean feather may be laid on, or a little flour may be sprinkled over the cut surface. In the case of cutting of the wattles it is a good practice first to apply a clamp to each wattle, and then after the wattles are ampu-

tated apply an astringent, such as tincture of ferric chloride, before releasing the clamps.

Testing for Fertility.—It is a good plan to make up matings two or three weeks before eggs are to be saved for incubation in order to determine whether or not good fertility may be expected. This is particularly important in the case of valuable breeding stock, more particularly male birds that have proved to be of superior breeding worth. It has been found at times that a male bird refuses to mate with certain females or vice versa, and testing for fertility before hatching eggs are to be saved for incubation in the case of trap-nested flocks allows time to make any necessary changes.

Good Fertility in 5 Days.—It is possible to secure a fertile egg approximately 24 hr. after copulation takes place, but a high percentage of fertile eggs is not likely to be obtained within 5 to 7 days after making up a mating. In order to secure maximum fertility before starting to save eggs, it is well to make up the matings at least 10 days in advance.

Proportion of Sexes.—Males differ among themselves regarding their ability or inclination to mate with different numbers of females, as good fertility sometimes being secured from a mating of one male mated to 30 or 40 females as from another male mated to 12 to 15 females. The vigor and individuality of the male seem to be the important factors in determining the approximate number of females to which he should be mated. Males of the Mediterranean breeds may be mated, on the average, with a few more females per male than males of the heavier breeds. Pen matings, where one male is mated with a given number of females, should consist of about 12 or 15 females, depending upon the breed and age of the male. Flock or mass matings, where a number of males are mated with the entire flock, should consist of one male to every 15 or 18 females, depending upon the breed and age of the males.

Age of Breeders.—Under ordinary circumstances cockerels give better results in fertility than cocks, and usually as the age of the male increases his fertility decreases. This is especially true in the case of males of the heavy breeds, so that rarely is it advisable to use males over 2 years old unless they have proved to be valuable breeders, in which case they should be mated to a limited number of females.

Pullets and yearling hens usually give about the same results in fertility, sometimes with a slight advantage in favor of pullets. After their yearling year, fertility in females usually declines. Evidence secured from different flocks shows that pullets that give better results in fertility than other pullets tend to give better results in fertility as yearlings.

Good Fertility for 10 Days after Matings Discontinued.—While it is possible to secure a fertile egg as long as 21 days after copulation has

taken place, the per cent of fertile eggs tends to decline about the fifth day and declines sharply following the tenth day after the males have been removed from the breeding pens.

In pedigree breeding work when it is desirable to know for certain the male parentage of every chick hatched, the substitution of one male for another should not be made for 3 weeks. On the other hand, carefully controlled tests have shown that when a second male replaces the first one in a breeding pen there is practically little overlapping in the fertilization of eggs by the spermatozoa of the two males, the spermatozoa of the second male fertilizing practically all of the eggs about 10 days after the substitution.

Artificial Insemination.—When copulation takes place between the male and female chicken the male ejaculates semen containing spermatozoa, the number of which may vary from a few thousand to several million at each ejaculation.

A very successful technique has been developed at the National Agriculture Research Center for securing sperm from the male by artificial stimulation and for transferring it to the exposed orifice of the oviduct of the female. This method is extremely useful in mating birds artificially that differ to such an extent in body size that normal mating is physically impossible. The method might also be used to advantage in mating a large number of females to a valuable male breeder as well as in securing fertile eggs from laying hens kept in batteries. Doses of 0.1 c.c. of semen administered once a week were observed to give good fertility.

BREEDING FOR HIGH HATCHABILITY

By the term hatchability is meant the qualities of a fertile egg that prevent or enable the hatching of a chick therefrom under ideal or normal conditions of incubation. It is obvious, of course, that faulty conditions of incubation may affect hatching results, thus making it impossible to determine the hatchability of all eggs set. Hatchability is expressed in terms of a percentage, which is obtained by multiplying the number of chicks hatched by 100 and dividing the product by the number of fertile eggs set.

Egg Characters and Hatchability.—It has been demonstrated that hatchability is not affected by the normal variations that occur in most of the characters possessed by eggs, such as shape, length, breadth, specific gravity, the thickness of the inner and outer shell membranes and shell, and shell color. On the other hand, in the case of each of several flocks in which there was considerable variation in egg size, it has been found that those eggs which approximated the standard weight of 2 oz. or 56.7 g. per egg hatched better than the smallest and the largest eggs,

especially the latter. The general situation that prevails in many flocks is shown in Fig. 32.

Evidence obtained recently indicates that eggs having the greatest weight of albumen, or white, tend to hatch less well than other eggs, and eggs having the greatest weight of thick white also tend to hatch less well than other eggs. Apparently the per cent of thick white of the total white per egg is not related to hatchability.

Egg Production and Hatchability.—From various observations made on the relationship between the egg production of the dams prior to and during the breeding season and the hatchability of their eggs, it has been shown that good hatchability is generally associated with good egg production. In other words, the eggs of the best layers tend to hatch just

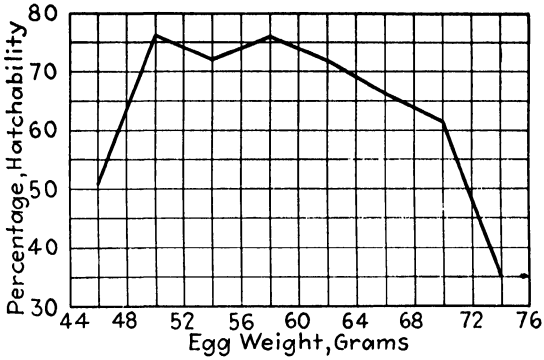


FIG. 32.—Showing the relationship between hatchability and average egg weight per bird. Eggs approximating the standard weight of 2 oz. per egg tend to hatch better than others. (*Godfrey*, 1936.)

as well as and in many cases better than the eggs of the poorest layers.

Lethal Genes and Hatchability.—Since it has been shown in the preceding chapter that there are certain genes that have a lethal effect on the developing embryo when the genes are in a homozygous condition, it is advisable for the poultry breeder who practices pedigree-breeding work for the development of a superior strain to examine his hatching records carefully with a view toward identifying the sires and dams carrying the lethal genes in a heterozygous condition. A sire and dam each carrying the lethal in a heterozygous condition, upon being mated together produce embryo progeny in the proportion of 3 normal to 1 possessing the lethal character. The same sire, mated to his daughters, produces embryo progeny in the proportion of 5 normal to 1 lethal or 7 normal to 1 lethal, depending upon the particular relationship he bore to his daughters.

Age of Parents and Hatchability.—The hatchability of eggs laid by birds of different ages has been investigated by a number of workers, whose results show for the most part that pullet eggs tend to hatch slightly

better than hen eggs. The pertinent data are given in Table 15, it being understood that the pullet and hen groups were composed of many different birds, although quite a few birds appeared in both groups, in the case of each breed.

TABLE 15.—PER CENT HATCHABILITY OF PULLET AND HEN EGGS, THE PULLET AND HEN GROUPS COMPRISING MANY DIFFERENT BIRDS
(Funk, 1934)

Breed	Pullets	Hens
W. Leghorns	82.9	74.5
R. I. Reds	78.9	70.7
Barred Plymouth Rocks	61.7	57.4
W. Plymouth Rocks	75.9	69.2

It should be pointed out that the pullets and hens were mated to different male birds, and the age of the hens is not given.

That the hatchability of the eggs of the same group of birds used two or more breeding seasons in succession tends to decline is shown in Table 16.

TABLE 16.—PER CENT HATCHABILITY OF EGGS LAID BY GROUPS OF FEMALE BREEDERS USED TWO OR MORE BREEDING SEASONS
(*a*, Hyre and Hall, 1932; *b*, Warren, 1934)

Breed	Age of female breeders			
	Pullets	2d year	3d year	4th year
W. Leghorns[a]	54.3	52.4		
Heavy breeds[a]	49.1	52.1		
W. Leghorns[a]	....	61.4	53.2	
W. Leghorns[a]	....	62.1	54.8	46.3
W. Leghorns[a]	....	62.1	58.9	57.0
W. Leghorns[b]	70.1	62.7		
W. Leghorns[b]	75.0	65.8	70.0	
W. Leghorns[b]	....	76.7	65.6	
W. Leghorns[b]	....	78.0	72.4	60.7
R. I. Reds[b]	55.0	43.9		
R. I. Reds[b]	60.0	53.3	49.2	
R. I. Reds[b]	....	64.1	62.5	
R. I. Reds[b]	....	69.2	65.8	54.2

It should be observed that different male birds were used with the females of different ages and that conditions of incubation may have varied from one year to another. Nevertheless, the data in Table 16 show that in spite of these and other factors that may have affected the

hatchability of the eggs of any of the groups of birds, there is a tendency for hatchability to decrease as breeding females become older.

Data on hatchability in relation to the age of the male bird are very meager, but it is probably true that, for the average male, the influence on the hatchability of the eggs of the females with which the male is mated does not decline to the same extent as his influence on fertility declines with advancing age.

Practical Suggestions.—It is possible to improve the hatchability of a flock by the proper selection of the breeding stock from year to year. The poultry breeder who trap-nests his female breeders and carries on pedigree breeding work should select his birds for future breeding purposes from among the progeny of sires and dams that give the best results in hatchability.

If the hatchability of a family or strain is low, it could be improved by securing a male from a family or strain noted for high hatchability. Careful records should be kept on the hatchability of the eggs laid by each dam, particular note being made of high early or late embryo mortality during the incubation period. Indications of the presence of lethal genes should be given special consideration. Females of superior breeding worth that give good hatchability when first used as breeders should be used for several years.

The poultry breeder who does not trap-nest his female breeders in order to carry on pedigree-breeding work should not expect to make the same progress in improving hatchability as the pedigree breeder who selects his future breeding stock on the progeny-test basis. Nevertheless, it is possible for the poultry breeder who does not carry on pedigree-breeding work to improve the hatching quality of the eggs laid by his flock from year to year. If the hatchability of the eggs of his flock is low as a result of poor inheritance, male breeders could be purchased from a pedigree-poultry breeder whose flock is noted for its high hatchability.

BREEDING FOR VIABILITY AND GOOD RATE OF GROWTH

Mortality takes entirely too heavy a toll in most flocks of chicks and laying pullets. Much of the mortality is undoubtedly due to faulty methods of management, including the diet that is fed, but in many cases it is due primarily to the low resistance of the stock to invasions of disease of one kind or another.

The pullorum disease often causes heavy mortality in chicks, especially during the first two or three weeks. This disease is mentioned here not because it is inherited in the same sense as shape of comb or color of skin but because the organism that causes the disease passes from the infected hen to the chick through the medium of the egg. Since chicks infected with pullorum disease frequently suffer heavy mortality, it is advisable

to have the breeding stock tested for the disease, and all reactors promptly removed.

The poultry breeder who carries on pedigree-breeding work should keep careful records of the mortality that occurs among the chicks secured from each dam and from each sire. Families in which the lowest mortality occurs should be the ones from which future breeding stock is selected, provided, of course, that these families are satisfactory with respect to other characters.

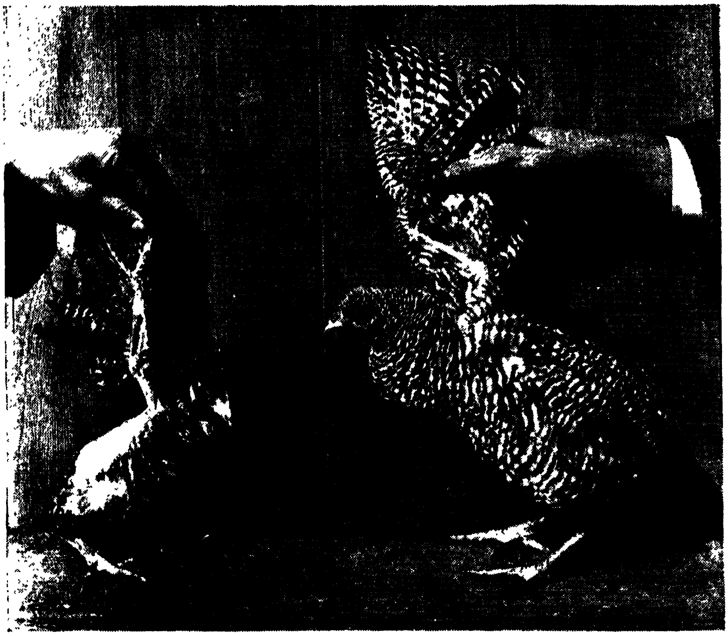


FIG. 33.—Showing great difference in the feathering of Barred Plymouth Rock broilers of the same age. Poor feathering is frequently accompanied by slow rate of growth. (*U. S. Dept. Agr.*)

Several lines of evidence have been secured from different sources indicating that it is possible to reduce mortality and increase longevity in the stock raised each year by breeding only from yearling and older hens. A breeding program based on the viability of the progeny should prove to be very worth while.

The same principle should be applied in the selection of stock for future breeding purposes from among the laying pullet progeny of dams and sires in which mortality has been the lowest, provided the family average egg production and other characters are satisfactory. The poultry breeder should adopt as his objective the development of a strain resistant to disease.

At the Illinois Experiment Station it has been shown that birds differ in their resistance to the organism causing pullorum disease, and at the

Iowa Experiment Station it has been demonstrated that birds differ in their resistance to fowl typhoid. At other experiment stations evidence has been secured indicating that birds differ in their resistance to fowl paralysis. The results of work done at the Kansas Experiment Station indicate that strains of chickens differ in their resistance to an internal

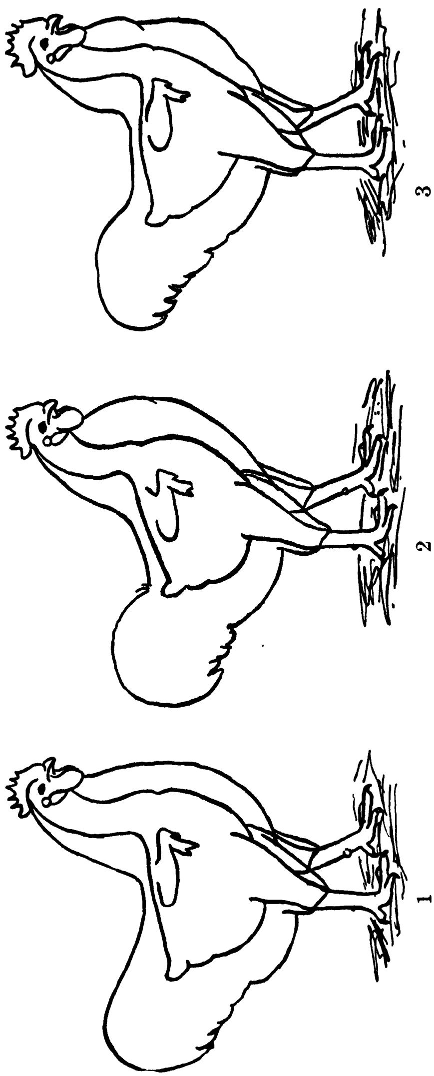


FIG. 34.—Showing contrasts in body type. Number 1 shows the ideal body type which gives the desirable market carcass. The keel runs approximately parallel to the back and is carried well forward. In number 2 the legs are set too far back on the body, giving the bird an upright carriage. Number 3 shows a very undesirable type, with a shallow breast and lack in depth of abdomen. (*Dominion Dept. Agr., Canada.*)

nematode parasite, *Ascaridia lineata*. From these various lines of work it is clearly apparent that by the selection of breeding stock on the progeny-test basis it should be possible to develop strains of chickens highly resistant to these diseases.

Rate of growth and rate of feathering should also be taken into consideration in the selection of breeding stock. Strains of chickens fre-

quently differ to a considerable extent with respect to both of these characters, and in strains characterized by slow rate of growth and poor feathering in the growing stock considerable improvement is possible through the intelligent selection of breeding stock from year to year. In

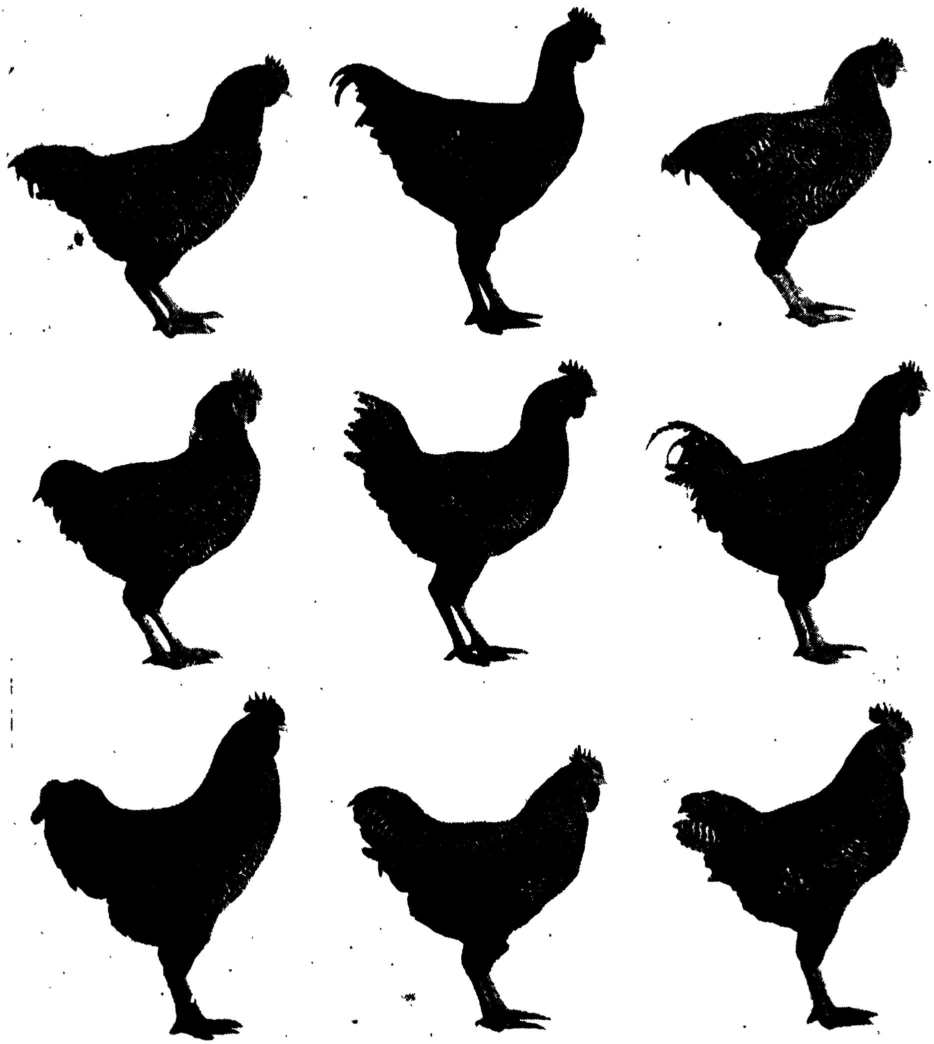


Fig. 35.—A sire, shown in the center of the figure, surrounded by 8 of his sons. The sire should never have been used as a breeder for it is clearly apparent that he transmitted excessive length of leg, shallow-breastedness, and lack in depth of body to his progeny. It is the kind of progeny produced that determines the breeding worth of a parent. (*Maw*, 1938.)

studies conducted at the Maine Experiment Station it was found that there was more mortality among chicks that grew extremely slowly or excessively fast as compared with chicks that grew at what might be called a normal rate.

Those interested in the development of strains most suitable for broiler production should select rigidly against poor feathering over the backs up to at least 8 weeks of age, particular care being taken to eliminate from the breeding pen the sires and dams that produce the poorly feathered

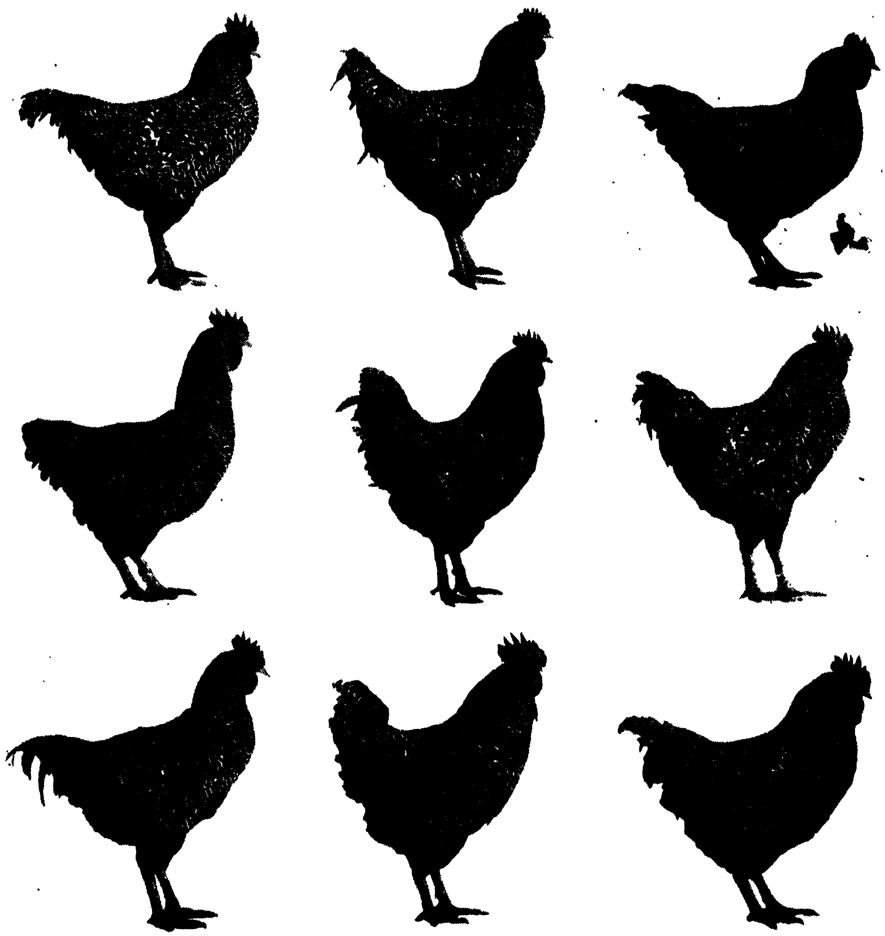


FIG. 36.—A sire, shown in the center of the figure, surrounded by 8 of his sons. The sire and his progeny represent the desirable kind of market bird, having well proportioned bodies of good depth, with good length of keel, giving a prominent breast. Breeding stock should be selected for meat-producing ability as well as for egg production. (*Maw*, 1938.)

broilers. The selection of the breeding stock on the basis of the rate of growth in their progeny up to 8 weeks of age should also be practiced, for evidence has been submitted showing that rate of growth to 8 weeks is apparently a separate heritable characteristic.

The relatively slow rate of feathering characteristic of Plymouth Rocks, Rhode Island Reds, Wyandottes, and similar breeds has been

shown to be dominant to the more rapid rate of feathering of Leghorns and similar breeds. Occasionally, however, early feathering chicks are to be found among the heavy breeds, as evidenced by the length of wing and tail feathers of the chicks at 10 days of age. By using such chicks, upon their reaching maturity, as foundation stock it is possible to develop an early feathering strain in any heavy breed.

Crossbreeding stimulates the rate of growth for the first few weeks, but the adult size of the crossbred progeny is usually about midway between the average adult size of the parental breeds that are crossed.

Poultry breeders interested in developing strains for egg- and meat-production purposes should select their breeding stock on the basis of standard-bred weight, avoiding the excessively small and large birds. Special attention should be given to the width of the back in relation to the length of the body.

Crooked keels have been shown to be inherited in at least one strain of chickens, and where they occur in other strains in sufficient proportion to affect the value of the birds when marketed they should be rigidly selected against in the breeding program.

BREEDING FOR GOOD EGG PRODUCTION

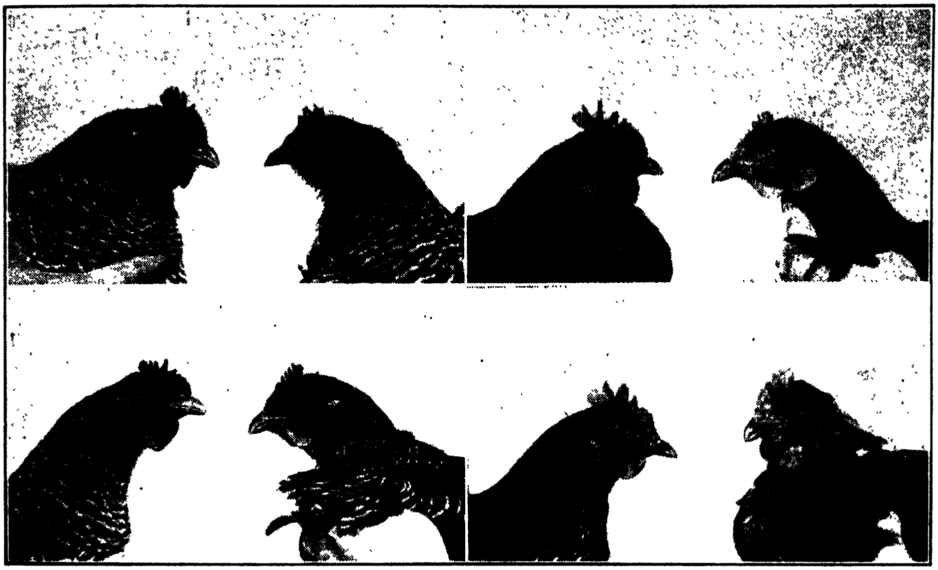
Except for certain specialized broiler-producing areas in the United States, the production of eggs has been the factor of greatest economic importance in poultry raising as far as the chicken industry is concerned. For the most part, therefore, the problem of the poultry breeder has been how to develop efficient egg-laying strains, at the same time giving due consideration to the economic importance of meat production. The greatest efficiency in egg production can be developed only in a flock that is bred for the various egg-production characters and where selection is carried on to eliminate the poor layers.

The physical appearance of a bird is of service in distinguishing the layer from the nonlayer, and certain physiological changes that take place in relation to egg production serve to indicate the approximate length of time that a bird has been laying.

Since egg production of itself is not a reliable index of breeding worth, the selection of the laying flock must be supplemented by a constructive breeding program which involves not only records of production but pedigrees and, most important of all, progeny tests. At the same time, the poultry breeder should always remember that, although the breeding program may be the soundest that it is possible to develop, no mating can ever be made that can be *guaranteed* to produce outstanding progeny. The best that the poultry breeder can hope for is to be able to identify sires and dams of superior breeding worth which when mated can reason-

ably be expected to produce progeny of outstanding merit with respect to the characters for which the flock is being bred.

Selection on Basis of Physical Appearance.—There are certain physical characters the appearance of which indicates whether or not a bird is in laying condition. If the comb and wattles are fully developed, bright red, and waxy in appearance, the bird is probably laying heavily; but if they are cold, dried, and shrunken, the bird is not laying. The small, round vent of the pullet becomes enlarged, oval in shape, and moist when the bird is in active laying condition. The pubic bones, two small bones



204 eggs. 69 eggs. 205 eggs. 30 eggs.
288 eggs. 81 eggs. 263 eggs. 155 eggs.

FIG. 37.—The shape of the head is not an indication of laying ability, except that the "beefy" type indicates a poor producer and an extremely narrow head is undesirable. (*U. S. Dept. Agr.*)

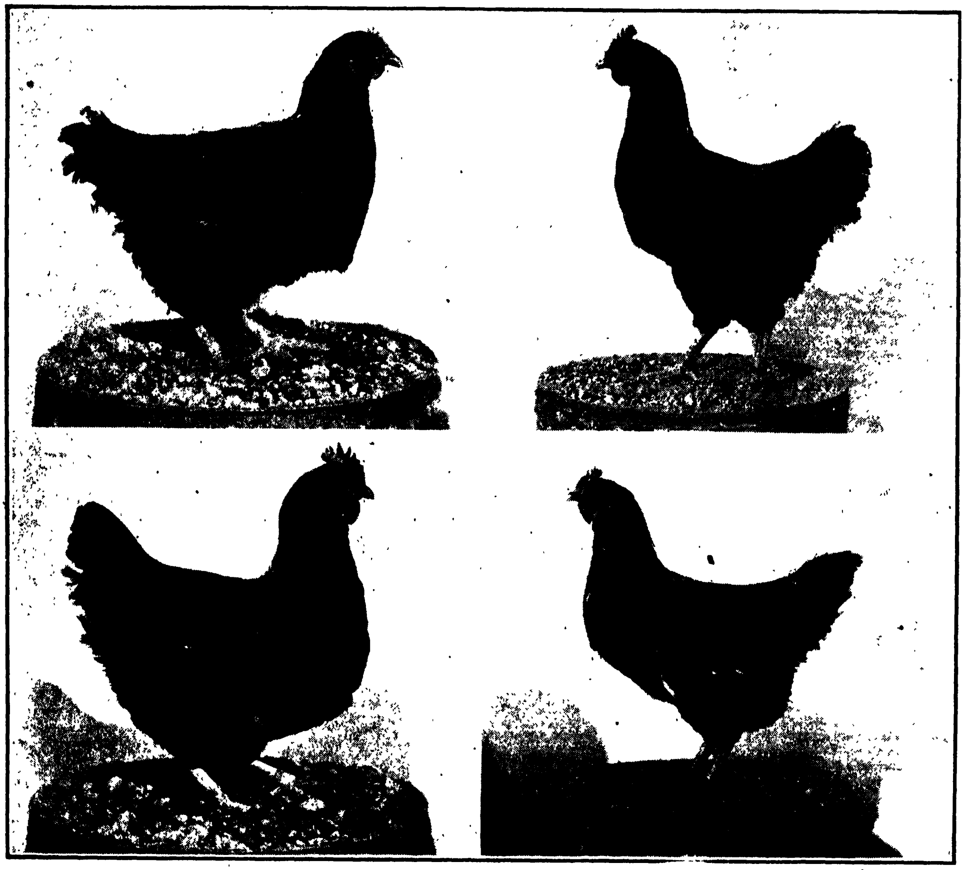
at the sides of the vent, become spread apart when the bird is in laying condition, and continuous production causes them to become thin and pliable. The abdomen, which contains most of the digestive and reproductive organs, should be of good size, and the skin covering the abdomen should be soft and pliable, in contrast to the thick and coarse skin often observed in poor layers.

Neither the shape of the head nor the shape of the body is a reliable indication of laying ability, although birds with extremely narrow or very coarse and "beefy" types of heads and bodies are usually poor layers.

Selection on Basis of Physiological Changes.—Careful observation has shown that certain physiological changes take place in the body of the bird as egg production continues. The two physiological changes of greatest importance that are useful in determining persistent layers are

the bleaching of the yellow pigment in the skin of yellow-skinned breeds and the time and duration of the first annual molt.

In all American and other yellow-skinned breeds there is usually an abundance of yellow pigment in the beak, shanks, toes, vent, and eye ring and in the white of the ear lobe of breeds having normally white ear lobes.



30 eggs. 231 eggs.
137 eggs. 272 eggs.

FIG. 38.—The shape of the body, as judged in live birds, is not an indication of laying ability, but physiological changes that take place in its body are measures of performance. (*U. S. Dept. Agr.*)

When a pullet starts to lay, the yellow pigment of the feed, called "xanthophyl," is diverted to the yolks of the eggs instead of going to the beaks, shanks, and other parts noted previously. As long as egg production continues, these parts gradually lose their pigment so that they become bleached in appearance. It follows, therefore, that the longer a bird continues to lay the greater the degree of bleaching. The yellow pigment does not return to the beak, shanks, and other parts until production ceases.

Yellow corn and green feed contain xanthophyl; but if white corn and other feeds that do not contain this yellow carotinoid pigment are fed, the beaks and shanks may be relatively pale even though the birds may have laid but few eggs. Therefore, the selection of persistent layers on the basis of changes in pigmentation should always take into account the kind of feed given the laying stock.

When yellow-skinned breeds are given feeds rich in the carotinoid pigment called xanthophyl, the extent of the bleaching of the vent, beak, and shanks serves as a very good indication of previous egg production.

TABLE 17.—AVERAGE ANNUAL EGG PRODUCTION OF GROUPS OF WHITE LEGHORN HENS SELECTED ON THE BASIS OF VENT, BEAK, AND SHANK COLOR
(Data of Blakeslee, Harris, Warner, and Kirkpatrick, 1917)

Color class	Number of birds and mean annual production					
	Vent		Beak		Shanks	
	Birds	Production	Birds	Production	Birds	Production
Pale	101	189.5	114	184.3	141	178.6
Medium	91	152.2	80	163.3	104	160.5
Yellow	183	136.3	181	131.8	130	123.4
Entire flock	375	154.5	375	154.5	375	154.5

The order in which the pigment disappears from different parts of the bird is first from the vent; then from the eye ring, which is formed by the inner edges of the eyelid; then from the ear lobes of breeds having normally white ear lobes; then from the beak, beginning at the base and extending toward the tip; and finally from the shanks, disappearing first from the front of the shank and later from the rear. Under average conditions a completely bleached beak indicates that the hen has been laying for 4 to 6 weeks, whereas completely bleached shanks indicate that the hen has been laying for 15 to 20 weeks. When laying ceases, the pigment reappears in the different parts of the body in the same order in which it disappeared.

Under normal conditions the average laying bird usually undergoes her first complete annual molt at the conclusion of what is known as her first year of laying. The time and duration of the first annual molt are important points in identifying the most persistent producers. Birds that molt early are usually the poorest layers, and, furthermore, the bird that is a poor layer usually stops laying in July and takes a relatively long time to complete her molt. Extremely early molters are often out

Good head.	Poor head.
Good width between pelvic bones.	Poor width between pelvic bones.
Good body capacity.	Poor body capacity.

FIG. 39.—Three important steps in judging hens for laying condition and body capacity. (*Ralston Purina Mills.*)

of production from 4 to 6 months and usually do not start their second laying year until December or January. Late molters, however, after a rest of 2 or 3 months, also begin to lay in December or January.

It usually takes about 6 weeks for a wing feather to grow out in either a low or a high producer, but the latter grows more feathers at a time, thereby completing the molt more quickly than a low producer. Some very high-producing hens take only a 4- or 5-week rest period. Exceptionally persistent producers sometimes have even shorter rest periods, production continuing during August, September, October, and November. Hens of this type usually begin to lay again before the new plumage is fully grown out. When the hen is molting, the feathers on different parts of the body are usually shed in the following order: head, neck, breast, body, wings, and tail. In some individuals a few tail feathers may be shed before the wing feathers. Shortly after the old feathers are dropped the new ones come in.

Early-hatched or early-maturing pullets sometimes have a partial molt in the fall of the year in which they were hatched, following a short period of production. The neck and tail feathers and one or two primaries (the stiff flight feathers seen on the outer part of the wing when it is spread out) may be shed during this molt; but the new primaries do not grow out to full length, and there is usually a break between the old and the new ones. During this molting period egg production usually stops, but to avoid this period of nonproduction, many poultrymen try to keep their early hatched pullets from going through a partial molt, although it is exceedingly difficult to check the partial molt; it may be avoided, however, by hatching at a later date.

When the selection of layers is made in August or September, toward the close of the first laying year, the condition of the plumage is good evidence as to whether or not the birds are persistent producers. The plumage of the persistent layers shows wear and tear from constant visits to the nest. The early-molting birds will have a growth of new feathers, the webs of which are glossy and bright in contrast to the dry, frayed webs of the old ones. The new quills are large, full, and soft, whereas the quills of the old feathers are small, hard, and almost transparent. A few pinfeathers in the neck may indicate a short molting period, but when shedding extends to the body and wings the molt usually becomes a complete one. A bird usually stops laying when molting the wing feathers but may lay while molting in other parts of the body. If the body weight is maintained, however, exceptionally high-producing hens may continue laying until the wing molt is considerably advanced.

Ordinarily it is possible to estimate when the molt began by counting the primary feathers in the wing. The primary feathers are the stiff flight feathers seen on the outer part of the wing when it is spread out.

The secondaries are also large and stiff, but they are found on the inner part of the wing and close to the body of the bird when the wing is folded in its natural position. The primaries are separated from the secondaries by a much shorter feather, known as the axial feather, which grows out at the wing joint.

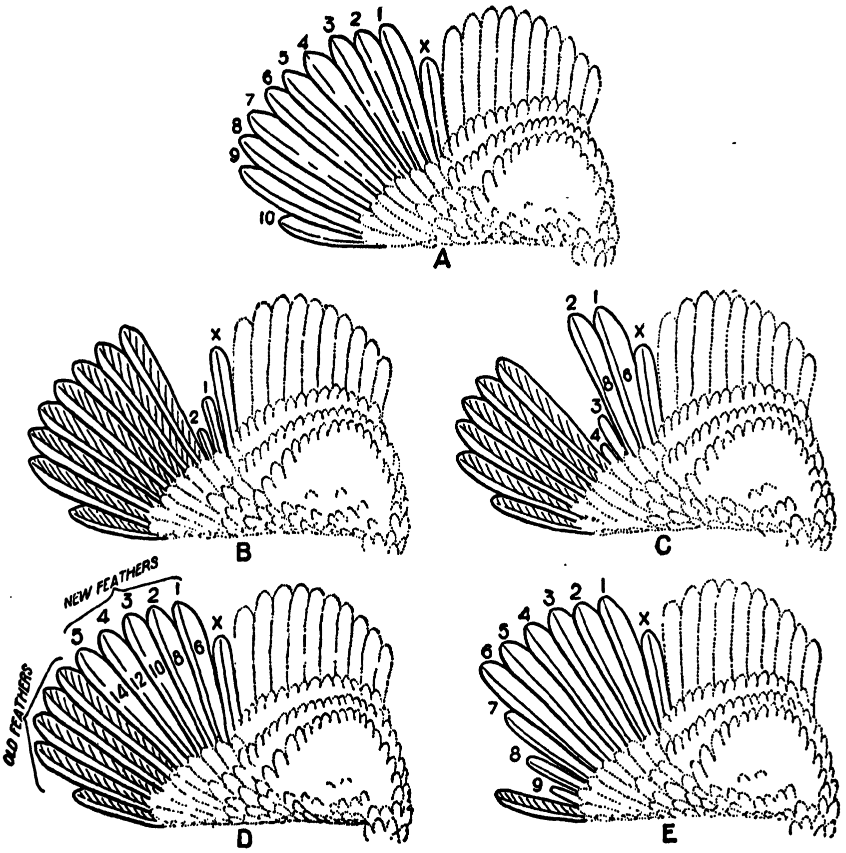


FIG. 40.—*A*, a normal wing showing the primary feathers, 1 to 10. They are separated from the secondary feathers (in dotted outline) by a short axial feather, *X*. *B*, the beginning of a wing molt. 1 and 2 are new feathers growing in. *C*, an 8-week molt. 3 and 4 are not counted until fully grown. *D*, an instance (abnormal) in which five feathers only were molted. *E*, a wing completing a normal molt. (*Kansas Agr. Exp. Sta.*)

There are usually 10 primary feathers in each wing, and when the complete body molt begins the first primary to be dropped is the inner one next to the axial feather. In the case of the early molter, 2 weeks after the first primary is dropped the second one is shed, and at 2-week intervals each subsequent primary is shed. In order to estimate the time elapsing since the molt began, 6 weeks should be allowed for the first mature new primary feather, and 2 weeks for each additional full-grown one. Thus a wing having four new full-grown primaries shows that the

bird had been molting 12 weeks. If the molt has just begun and none of the primaries is yet fully grown out, calculation must be made on their present growth. Approximately two-thirds of this growth is made during the first 3 weeks, and the other third during the last 3 weeks. A half-grown primary, therefore, indicates about 2 weeks of growth.

Usually there is little difficulty in distinguishing the new primary feathers from the old ones because the new feathers are clean and bright with a soft quill and broad outline, whereas the old primaries are much more pointed in shape and are rather worn. The primaries of the persistent producer are molted rapidly and in a manner similar to that of the body plumage. Instead of being renewed one at a time, as in the early molter, a group of two or more primaries of the same length may grow simultaneously. When such a condition exists, all the new feathers of the same length are considered as one in calculating the length of time that has elapsed since molting began.

High-producing hens sometimes do not molt all their primary feathers but continue to carry some of the old ones into the next year. By growing the primaries in groups of two or more or carrying over the old primaries, many high producers materially shorten the time necessary to complete their wing molt. It is apparent, therefore, that the time and duration of the molt serves as a good criterion of persistent production.

A carefully planned system of selection based upon the bleaching of the pigment of the beaks, shanks, and other parts of the body and thorough observations on molting are extremely useful in segregating the high from the low producers in any flock.

Selection on Basis of Egg Records.—With a few outstanding exceptions, most of the poultry breeders in the United States apparently attach considerable significance to the first-year egg records of the females. There is a widespread belief that the higher the first-year record of the dam the more eggs will her pullet progeny lay. In other words, it is claimed that the number of eggs a bird lays during her first laying year is a criterion of her breeding worth.

Data have been obtained from different sources which show that actually the first-year production record of a female is only of very limited value in predicting her breeding worth. A true test of the relationship that normally exists between the egg production of dams and the egg production of their daughters could be made only in the case of dams not selected on the basis of first-year egg-production records and complete families of daughters, *i.e.*, where no culling of pullets were practiced during the first laying year. In so far as is known, however, no such data exist, for the simple reason that in practically all projects on breeding for increased egg production, the dams are selected to a greater or lesser extent on the basis of their first-year records.

However, data are available that show the relationship between the egg production of selected dams and the egg production of unselected daughters, the records of all daughters except those that died being included. In Table 18 are given data on Rhode Island Reds at the National Agricultural Research Center and on White Leghorns at the Mount Hope Farm. The Rhode Island Red dams were selected on the basis of having laid a minimum of 200 eggs their first laying year, whereas in the case of the White Leghorn dams the minimum given in Table 18 is 181 eggs.

TABLE 18.—THE AVERAGE FIRST-YEAR EGG PRODUCTION OF THE DAUGHTERS OF DAMS CLASSIFIED ACCORDING TO THE RANGE IN EGG PRODUCTION OF THE DAMS

Range in egg production of dams	Average egg production of daughters		Range in egg production of dams	Average egg production of daughters	
	R. I. Reds	W. Leghorns[1]		R. I. Reds	W. Leghorns[1]
181 to 190	...	162	251 to 260	201	188
191 to 200	...	157	261 to 270	200	209
201 to 210	188	168	271 to 280	197	188
211 to 220	205	161	281 to 290	179	208
221 to 230	192	173	291 to 300	...	222
231 to 240	192	176	301 to 310	...	228
241 to 250	199	169	311 to 320	...	220

[1] Data from an unpublished paper by H. D. Goodale, 1935.

The data in Table 18 show no apparent relationship between the egg production of the dams and that of the daughters among the Rhode Island Reds, but they show a slight relationship between the egg production of dams and that of the daughters among the White Leghorns.

It is interesting to observe that the average egg production of the daughters of each of the first six groups of the Rhode Island Red dams was considerably higher than the average egg production of the daughters of each of the comparable groups of the White Leghorn dams. The Rhode Island Red data were obtained from matings of yearling and older hens made in three consecutive years, 1928 to 1930, inclusive, the dams being mated to males whose dams laid 200 or more eggs during their first laying year. The White Leghorn data were obtained from pullet matings made during the years 1923 to 1929, inclusive, and the low-producing dams listed in the table were used mainly during the first two or three years. Moreover, the sires used each year were selected on the basis of the records of egg production made by their sisters up to Feb. 1, from

which it may be assumed that the males selected one year were somewhat superior to those selected the preceding year. The use of sister-tested males should in itself tend to increase the egg production of the daughters raised each succeeding year, even if the dams' records of egg production had been the same for each of the 7 years.

Even so, it is apparent that the relationship between dam and daughter egg production is of a relatively low order. For instance, the group of White Leghorn dams with a range in production of 201 to 210 eggs had daughters that averaged 168 eggs, whereas the group of White Leghorn dams with a range in production of 271 to 280 eggs had daughters that averaged 188 eggs. The average egg production of these groups of dams differed by approximately 70 eggs, but their daughters' averages differed by only 20 eggs. The White Leghorn data show, however, that on the average the higher the egg production of the dams the higher the egg production of the daughters.

Those who hold that the egg-production record of a selected dam is an index of her breeding worth should examine carefully the source of the data on which their belief is based. In Table 18 it is shown that the White Leghorn dams that laid from 201 to 210 eggs had daughters that averaged 168 eggs each and that the dams that laid from 281 to 290 eggs had daughters that averaged 208 eggs each, the difference in the average egg production of the two groups of daughters being 40 eggs. On the other hand, the Rhode Island Red dams that laid from 211 to 220 eggs had daughters that averaged 205 eggs, whereas the White Leghorn dams that laid from 211 to 220 eggs had daughters that averaged 161 eggs, there being a difference of 44 eggs in the average production of daughters that came from dams with the same records. Then, again, those who claim that the first-year record of egg production of a bird is a good index of her breeding worth would have great difficulty in accounting for the fact that the Rhode Island Red dams with a range of 201 to 210 eggs and the White Leghorn dams with a range of 271 to 280 eggs produced daughters that had exactly the same average egg production.

Although the selection of dams on the basis of their first-year records of egg production is thoroughly justified, the data in Table 18 show that the production records by and of themselves are of very limited value. Some poultrymen have assumed, however, that if it can be shown that in certain flocks there is a slight correlation between dam and daughter egg production, then it must follow that in all flocks the selection of breeding stock on the basis of individual records would rather quickly raise the level of egg production. These poultrymen usually overlook the conditions involved in selecting the breeding stock in those flocks where a dam-daughter correlation has been shown to exist, and they fail to realize that these conditions do not apply to the great majority of poultry-breed-

ing flocks throughout the country. Most poultry breeders in the United States cull their pullet flocks rather closely, and many of them use individual records of egg production as the sole basis for selecting their breeding stock. While poultry breeders should be encouraged to select their breeding stock on the basis of production records, they should be cautioned not to attach too much significance to those records.

If the first-year egg-production records of a female served as an accurate index of her breeding worth, as some have claimed, the problem of breeding for increased egg production would be comparatively simple. The data in Table 19 show how divergent are the results sometimes secured from two groups of daughters produced by the same dam mated in different years to the same or to different sires. These data were obtained from the National Agricultural Research Center, the first five dams in the table being Rhode Island Reds and the second five White Leghorns. The daughters' averages given in the table were determined for all daughters produced by each mating except for birds that died.

TABLE 19.—THE AVERAGE EGG PRODUCTION OF EACH GROUP OF DAUGHTERS OF DAMS MATED TO THE SAME AND TO DIFFERENT SIRES IN TWO DIFFERENT YEARS

Dam No.	Sire No.		Dam's production	Average egg production of daughters	
	1st year	2d year		1st year	2d year
R. I. Reds:					
6024	176	176	212	217	189
6027	176	176	206	178	222
6401	334	334	233	214	184
5829	325	338	246	189	241
6142	351	368	242	182	220
W. Leghorns:					
2786	50	249	257	159	228
3472	100	248	235	212	172
3728	91	248	258	213	167
3845	91	248	262	175	202
3287	100	249	230	164	225

The data in Table 19 show that the same dam when mated to the same sire may produce daughters in two different years that differ in average egg production by as much as 40 eggs. When mated to different sires, the daughters of the same dam in successive years differ by as much as 60 eggs.

It is unfortunate for the poultry-breeding industry that many poultry breeders attach so much importance to individual records of production, especially since it has been shown that progress in breeding for increased

egg production is bound to be achieved very slowly as long as a record of egg production is the only basis used in selecting the breeding stock.

There are several reasons why the record of a bird's egg production may not be nearly so significant in indicating her breeding worth as many poultry breeders are inclined to believe. Egg production is a quantitative characteristic which is easily influenced by environmental conditions and by the diet given the laying stock. Poorly balanced diets, improper methods of feeding, poor housing conditions, sudden changes in temperature, internal and external parasites, and diseases of various kinds all significantly decrease production. There may be a vast difference between the number of eggs a bird actually lays and the number she might have laid if she had been kept under ideal conditions. Rarely do ideal conditions prevail, however, that enable a bird to lay the number of eggs of which she is potentially capable.

Selection on Basis of Pedigree.—By pedigree breeding in poultry is meant the mating of birds with pedigrees and keeping account of the parentage of the chicks produced so that their pedigrees are a matter of record. A bird's ancestry sometimes gives considerable information of value regarding its probable worth as a breeder. Of two birds with the same first-year egg-production records, the one with a good ancestry is to be preferred to the one with a poor ancestry. The chances are greater that the former will give better results in breeding than the latter; the chances are greater—but there is no guarantee that a bird of good ancestry will always produce good progeny.

Although a good pedigree is of importance in selecting breeding stock, there are certain limitations in the application of pedigree selection. For instance, very little significance can be attached to the individual records of egg production of ancestors beyond the third generation. Then, again, the greater the variation in the environmental conditions—including diet, method of housing, and the use of artificial lights—to which a flock is subjected over a period of years the less reliance can be placed upon the ancestors' records of production in the selection of progeny for future breeding purposes.

The data in Table 20, pertaining to Rhode Island Reds and White Leghorns, show that the higher the egg production of the three nearest female ancestors of both sire and dam the higher is likely to be the average egg production of their progeny. In the case of each flock, the environmental conditions were kept as uniform as possible from year to year.

Judging from the data in Table 20, it is apparent that the selection of breeding stock on the basis of ancestors' records of production to the third generation is of considerable importance. As a matter of fact, the more information there is in the pedigree concerning the records of egg production of the sisters of parents and grandparents, and the more

information there is concerning the breeding performance of parents and grandparents and their relatives, the greater the value of the pedigree in selecting breeding stock.

TABLE 20.—THE AVERAGE EGG PRODUCTION OF DAUGHTERS ACCORDING TO THE RANGE IN AVERAGE EGG PRODUCTION OF THE THREE NEAREST FEMALE ANCESTORS OF BOTH SIRE AND DAM

Range in average egg production of the three nearest female ancesters of both sire and dam	Average egg production of daughters		Range in average egg production of the three nearest female ancestors of both sire and dam	Average egg production of daughters	
	R. I. Reds	W. Leghorns[1]		R. I. Reds	W. Leghorns[1]
209 to 217	186	...	254 to 262	...	199
218 to 226	197	180	263 to 271	...	213
227 to 235	199	166	272 to 280	...	216
236 to 244	205	176	281 to 289	...	222
245 to 253	...	208	290 to 298	...	210

[1] Data from an unpublished paper by H. D. Goodale, 1935.

Selection on Basis of Progeny Test.—The supreme test of the worth of a bird as a breeder is the kind of progeny it produces. Thus in the case of a dam it is not her individual laying record that counts so much as the average laying record of her daughters, which is quite a different thing. Strangely enough, the first impetus given to progeny testing in breeding for increased egg production was the failure resulting from an attempt to develop an egg-laying strain through the selection of female breeders based entirely on their first-year records of egg production. Apparently, the first attempt at a state institution to improve egg production through selection was made at the Maine Agricultural Experiment Station. The work was carried on many years ago with Barred Plymouth Rocks, and the records show that over a period of 9 years the practice of selecting female breeders on the basis of their first-year trap-nest records failed to produce an increase in the level of egg production among the pullets raised each year.

The early work at the Maine Station, however, laid the foundation for later work which demonstrated the significance of the progeny test in breeding for increased egg production. Further breeding work with Barred Plymouth Rocks at the Maine Station demonstrated that by selecting cockerels and pullets for future breeding purposes each year from among the best families of that year a steady increase in the level of egg production was achieved. Cockerels and pullets to be used as breeders were selected from among the progeny of sires and dams that proved to be superior in breeding worth to other sires and dams. The progeny-

test method of selecting breeding stock has been used consistently for a period of years in the breeding of Rhode Island Reds at the Massachusetts Agricultural Experiment Station, where outstanding results have been achieved.

It is particularly important for poultry breeders to be able to identify sires of superior breeding worth because the average sire has about ten times as many chicks as the average dam. A practical way of applying the progeny test to sires without trap-nesting either the dams or their daughters may be easily carried out. Separate breeding pens are maintained in each of which one male is mated to the usual quota of females. The chicks from each sire are banded at hatching time so that the pullets can be distinguished from the pullets secured from other sires. The laying pullets from each sire are placed in separate houses or pens, and by comparing the average egg production of the pullets of each sire the breeder is able to determine which sires were superior in breeding worth.

The difference in breeding worth of sires mated to trap-nested Rhode Island Red dams having minimum first-year records of 200 eggs and White Leghorn dams having minimum first-year records of 225 eggs is shown in Table 21. The data were obtained from a few of the matings made at the National Agricultural Research Center. The records of egg production of all daughters placed in the laying houses, except for

TABLE 21.—AVERAGE EGG PRODUCTION OF DAUGHTERS OF DIFFERENT RHODE ISLAND RED SIRES MATED TO RHODE ISLAND RED DAMS THAT LAID 200 OR MORE EGGS AND OF DIFFERENT WHITE LEGHORN SIRES MATED TO WHITE LEGHORN DAMS THAT LAID 225 EGGS OR MORE

	R. I. Reds				W. Leghorns		
Sire No.	Average egg production of sire's mates	Number of daughters	Average egg production of daughters	Sire No.	Average egg production of sire's mates	Number of daughters	Average egg production of daughters
173	223	48	219	3	248	45	229
10,105	242	49	216	250	243	37	227
334[1]	231	37	211	249	243	71	206
338[1]	238	31	206	252	247	48	200
334[1]	242	32	205	91	254	46	199
330[1]	246	46	201	100	248	59	193
330[1]	250	38	195	259	243	69	185
200	243	52	193	254	237	51	179
338[1]	250	60	192	10,106	239	46	179
351	232	75	171	50	228	49	168

[1] These sires were used in two consecutive breeding seasons.

birds that died, were used to compute the average for each of the different groups of daughters. The mortality among Rhode Island Red daughters was 9.17, and among the White Leghorns 13.26 per cent. The average egg production of all the Rhode Island Red daughters was 192.03, and of all the White Leghorn daughters 192.85.

The data in Table 21 make it quite clear that certain sires were much superior to others from the standpoint of transmitting laying ability to their daughters. The sons and daughters of sires 173 and 3 are likely to be much better breeders than the sons and daughters of sires 351 and 50.

Some poultry breeders carry on progeny-testing work on an extensive scale and, from the various matings made, retain either all of the progeny or a sufficiently large number to make it possible to concentrate breeding work among families that have been developed from superior sires and dams. The record made of a random sample of the progeny, of course, gives the most accurate index of the breeding worth of the breeder's flock or mating. The data in Table 22 were obtained from two private poultry breeders who practiced no culling of the progeny of different sires.

TABLE 22.—THE AVERAGE EGG PRODUCTION OF DAUGHTERS OF DIFFERENT SIRES USED IN TWO PRIVATE BREEDING FLOCKS

Poultry breeder	Variety	Sire No.	Average egg production of sire's mates	No. of daughters	Average egg production of daughters
A	W. Leghorns	G10	264	76	219
		G8	276	84	218
		G4	262	80	209
		G7	261	135	198
		G6	276	108	191
		G2	274	105	166
		G11	285	114	163
B	W. Leghorns	1	283	130	243
		2	289	39	240
		3	259	55	228
		4	273	18	169
		5	255	33	152
	R. I. Reds	1	252	57	242
		2	277	104	235
		3	268	26	234
		4	237	39	168
		5	270	28	165

Poultry breeder *A* knows full well that sire G10, whose mates' average was 264 eggs and whose daughters' average was 219 eggs, is greatly superior in breeding worth to sire G11, whose mates' average was 285

eggs and whose daughters' average was 163 eggs. Likewise, *B*, with his White Leghorns, would pick sire 1, whose mates and daughters averaged 283 and 243 eggs, respectively, over sire 5, whose mates and daughters averaged 255 and 152, respectively. *B*'s Rhode Island Red sire 1 was mated to females that averaged 252 eggs, and his daughters averaged 242 eggs; whereas sire 5, although mated to females that averaged 270 eggs, had daughters that averaged only 165 eggs.

Although it has been pointed out previously that the ability to identify and make use of sires of superior breeding worth is of paramount importance in raising the level of egg production of the flocks of the country, nevertheless it is highly important to be able to identify a female of superior breeding worth, if for no other reason than to produce more superior males. Two private poultry breeders have submitted data giving the average egg production of the daughters of a few of the dams they have used. The data of *A* and *B*, given in Table 23, for White Leghorns and Barred Plymouth Rocks, respectively, are sufficient to show what can be accomplished.

TABLE 23.—AVERAGE EGG PRODUCTION OF DAUGHTERS OF DIFFERENT DAMS OF OUTSTANDING BREEDING WORTH

Breeder and variety	Dam No.	Dam's production	No. of daughters	Average egg production of daughters
A, White Leghorns	Y308[1]	299	23	243
	Y417[1]	260	39	253
	Y1095[1]	273	39	246
	A2711[1]	278	42	234
	A3131[1]	267	25	248
	B268[1]	276	27	238
	0401	275	15	255
	G2235	281	8	278
	P262	284	5	269
	P2494	270	9	252
	G712[1]	314	28	230
	K33916	312	19	203
B, Barred Plymouth Rocks	3232	258	8	223
	3392	254	8	234
	3846	215	18	215
	981	296	7	201
	984	214	8	228
	994	234	11	186
	2731	280	11	251
	3779	224	10	216

[1] These birds were used 2 years or more.

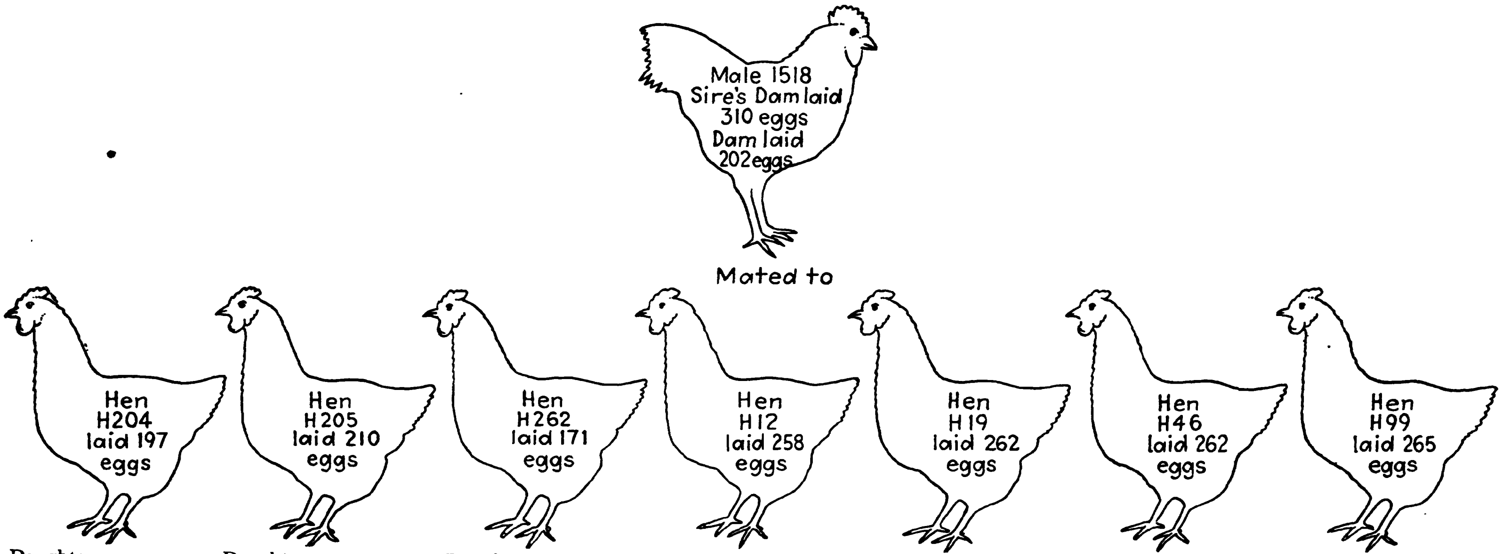
Even though some of the daughters of the different White Leghorn dams listed in Table 23 were culled during their first laying year, it is apparent that all of the dams are birds of considerable merit as determined by the progeny test. There was practically no culling in the case of the Barred Plymouth Rock groups of daughters.

It might be well to mention here that the most progressive breeders use every means available to identify superior sires and dams in their flocks. Among other things, in addition to the kind of progeny produced by different sires and dams, the production records of their sisters are usually taken into consideration. For instance, *A*'s White Leghorn dam A2711 had 11 sisters that averaged 240 eggs; dam A3131 had 12 sisters that averaged 256 eggs; dam G2235 had 12 sisters that averaged 255 eggs; dam P262 had 10 sisters that averaged 240 eggs. *B*'s Barred Plymouth Rock dam 3232 had 18 sisters that averaged 200 eggs; and dam 3779 had 12 sisters that averaged 219 eggs.

Then, again, many poultry breeders give considerable weight to pedigree in selecting their breeding stock. Such breeders should always remember, however, that certain things that the breeder may practice tend to lessen the value of the pedigree. As already pointed out, the greater the extent to which the diet and environmental factors governing egg production have been changed from year to year, the less significant are the records of egg production of the birds appearing in the pedigree of an individual. Again, it should always be kept in mind that the greater the extent to which culling was practiced in previous years, the less the value of the records of the birds that were retained and appear in the pedigree.

It is apparent, therefore, that even under the best circumstances there are a number of handicaps, to say nothing of the expense involved, under which the average poultry breeder must labor in his efforts to select sires and dams of superior breeding worth. Then, again, since the chicken is a relatively short-lived creature, and since sires and dams may be 3 or 4 years old by the time they have been proved to be of superior breeding worth by the progeny test, it is apparent that if their "blood" is to be perpetuated, their sons and daughters must be used for future breeding purposes. The use of these sons and daughters is sound breeding practice because they have a far greater chance of being superior breeders than the sons and daughters of unproved sires and dams.

A Sound Selection and Breeding Program.—It is all too true that many poultry breeders have been carrying on their breeding operations for years without having the slightest knowledge of the various egg-production characteristics their birds possess. On the other hand, the more progressive breeders, by their system of carefully tabulated records for individual birds and for the results secured from various matings, are



Daughters	Eggs laid
L 411	143
L 2571	221
L 2594	144
L 3224	179

Daughters	Eggs laid
L 453	137
L 2578	119
L 2613	180
L 3231	166
L 3249	199

Daughters	Eggs laid
L 196	229
K 223	218
K 255	215
K 311	201
K 319	181
K 330	211
K 366	164
K 407	150
K 498	116

Daughters	Eggs laid
L 28	210
L 51	242
L 2542	190
L 2547	234
L 2556	216
L 2626	234
L 3924	212

Daughters	Eggs laid
K 65	277
K 94	278
K 119	137
K 188	198
L 190	203
L 193	210
L 2503	144
L 2531	180
L 2532	187
L 2580	166
L 3202	168
L 3294	160
L 3423	222
L 3901	209

Daughters	Eggs laid
L 2513	105
L 2548	263
L 2576	157
L 2640	95
L 2643	190
L 3442	161
L 3912	196

Daughters	Eggs laid
L 139	224
L 346	164
I 359	222
L 2512	131
L 3203	168

FIG. 41.—It is the kind of progeny that a sire and a dam produce that determines their breeding worth. Hen No. 19 had a much larger family of daughters whose average egg production was much higher than those of hen No. 205 although both hens were mated to the same male, No. 1518. The sons of hen No. 19 should be considerably superior as breeders to the sons of hen No. 205. Progress is best achieved by progeny testing. (*Graham et al.*, *Ont. Agr. Coll.*)

well fortified with specific information that makes possible intelligent selection of males and females for future breeding purposes.

Poultry breeders have found that the observations made in the breeding of Rhode Island Reds during the last 30 years at the Massachusetts Agricultural Experiment Station have been of great help in deciding which birds to select as breeders. The station has made important contributions to the knowledge of the mode of inheritance of various characteristics of economic importance in poultry. Among other things, it has been observed that there are five principal characteristics that determine the number of eggs a bird lays during her first laying year.

Briefly, in order to lay well, a pullet should possess the five following characteristics: (1) early sexual maturity, (2) good rate of laying, (3) nonbroodiness, (4) absence of winter pause, and (5) persistence of production.

Numerous poultry breeders and workers at some of the state experiment stations take these five characteristics into consideration in the selection of layers to be used as future breeders. An analysis of the egg-production records of Rhode Island Reds and White Leghorns at the National Agricultural Research Center shows, however, that in these flocks winter pause has not been of great importance.

By sexual maturity is meant the age of the bird in days at the time she begins laying. Rate of laying is determined by figuring, on a percentage basis, the number of eggs laid from the date of the first egg to a given date in relation to the total number of days involved; or rate may be determined on the basis of average size of the winter clutch. A clutch is the number of eggs laid during successive days without any intervening days of no production. Broodiness is a simple characteristic to determine; the number of times a bird goes broody and the length of time she is broody are usually taken into consideration, or the percentage of birds in the flock that go broody is considered. Persistence of production simply means that the pullet continues laying well toward the close of her first laying year, which is 365 days from the date of the first egg.

If a White Leghorn or Rhode Island Red pullet is to lay approximately 200 eggs during her first laying year, the White Leghorn should start laying at about 160 or 180 days of age, and the Rhode Island Red at about 180 or 200 days. Pullets of both breeds should lay at about the rate of 60 per cent, or at least 4 eggs per clutch. There should be practically no broodiness. They should lay approximately 25 eggs during August and September of the year following that in which they were hatched.

Each of these characteristics can be developed in a flock by the adoption of a sound breeding program. The results obtained with the Massachusetts Rhode Island Reds show what can be accomplished (Table 24).

Since many poultrymen who keep Plymouth Rocks, Rhode Island Reds, Wyandottes, and similar breeds often experience difficulty in

TABLE 24.—INCREASE IN LEVEL OF EGG PRODUCTION WITH IMPROVEMENT IN FOUR CHARACTERISTICS IN RHODE ISLAND REDS AT THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION
(Hays, 1936*b*)

Year	Pullets	Sexual maturity, days	Rate of laying[1]	Non-broodiness, per cent	Persistence, days	Average egg production
1920	162	200	2.7	54	331	200
1921	440	211	3.3	55	304	198
1922	565	197	2.7	71	322	200
1923	472	209	2.4	73	323	189
1924	422	196	2.5	67	327	196
1925	553	192	3.1	58	330	205
1926	479	199	2.7	81	331	205
1927	551	185	3.5	90	321	197
1928	560	196	3.4	72	335	215
1929	507	197	3.1	87	330	208
1930	461	191	3.7	78	340	214
1931	462	189	3.8	84	344	234
1932	377	202	3.3	88	338	222
1933	504	194	3.3	95	342	214

[1] Average number of eggs per clutch.

eliminating broodiness from their flocks, it is interesting to note that the number of birds in a flock that go broody, as well as the length of time they spend in being broody, can be materially reduced if every time a hen goes broody she is banded with a celluloid band and is never used as a breeder. From the practical standpoint, the broody hen should be "broken up" as quickly as possible, but she should always be banded so that at the end of the season she will not be kept for breeding purposes the next year. The economic importance of reducing broodiness is shown by the difference in egg production between Rhode Island Reds that went broody and those that showed no broodiness in flocks kept at the National Agricultural Research Center. The birds that went broody once or oftener during the year averaged 180 eggs, while those that did not go broody averaged 205 eggs.

Now that a sound program of selection has been outlined, all that remains is to outline a breeding program to accompany the selection program. It has been pointed out in previous sections of this chapter that the greatest progress in developing high-laying strains is possible only when the progeny test is applied. The first step, therefore, in the breeding program is to determine which of the different male birds used proved to be the best breeders. The female progeny of one male should be compared with the female progeny of each of the other males on the basis of the four factors of major importance: sexual maturity, rate of

laying, nonbroodiness, and persistence of production. Having determined which males proved to be of superior breeding worth, the breeder's next step is to compare the female progeny of each of the hens to which a superior male was mated.

The breeding program should be based on the selection of outstanding families. Sires and dams that have proved to be of outstanding breeding worth should be used for as many years as possible. Also, their progeny should be given preference when the time comes to select future breeders. Since the average sire and dam are relatively short-lived creatures, however, it is necessary to adopt the best system possible in the selection of younger birds for breeding purposes, especially cockerels. For this

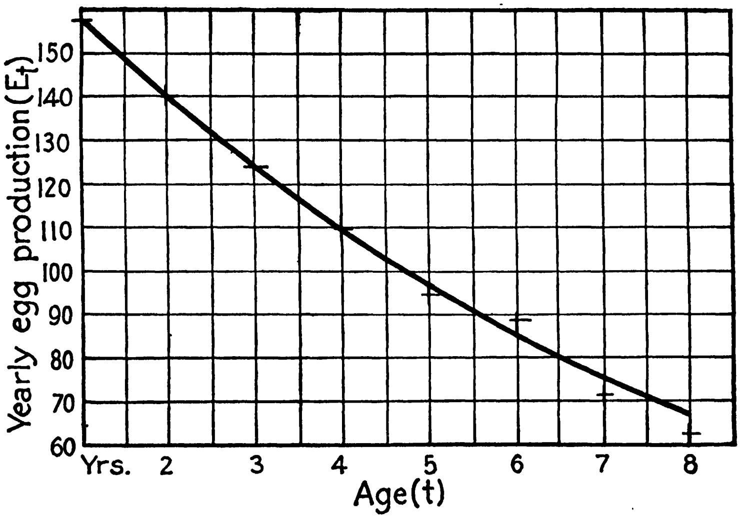


FIG. 42.—The decline in egg production with age in the domestic fowl. The smooth line represents the computed values; the crosses represent the observed values. The observed values during the seventh and eighth years are not reliable owing to the small number of individuals represented in the averages. (*Brody, Henderson, and Kempster.*)

purpose, it is necessary to determine which family of full sisters is giving the best performance during the fall and early winter from the standpoint of early sexual maturity and rate of laying, because the cockerels must be selected about the first of the year. Cockerels for future breeding purposes should be chosen from the families in which the full sisters are outstanding.

There are other factors than those pertaining to egg production that should be taken into consideration in the selection of birds for breeding purposes. Those of economic importance include size of egg, shell color and texture, and interior quality. The importance of these factors in developing a breeding program is discussed subsequently.

Importance of Long-time Production.—Although it has been demonstrated that in the case of most birds there is a decline in second-year

egg production as compared with first-year egg production and a decline in third-year egg production as compared with second-year egg production, nevertheless it has also been demonstrated that there is a sensible correlation between first- and second-year egg-production records. In other words, pullets that lay better than others the first year are also inclined to lay better the second year.

Under ordinary circumstances the decline in second-year egg production as compared with first-year egg production amounts to about 20 per cent. In other words, a first-year record of 200 eggs is apt to be followed by a second-year record of about 160 eggs. Birds that lay well over a period of years and have proved to be good breeders as yearlings and two-year old birds should be used as breeders for as many years as possible, and their progeny should be selected for future breeding purposes.

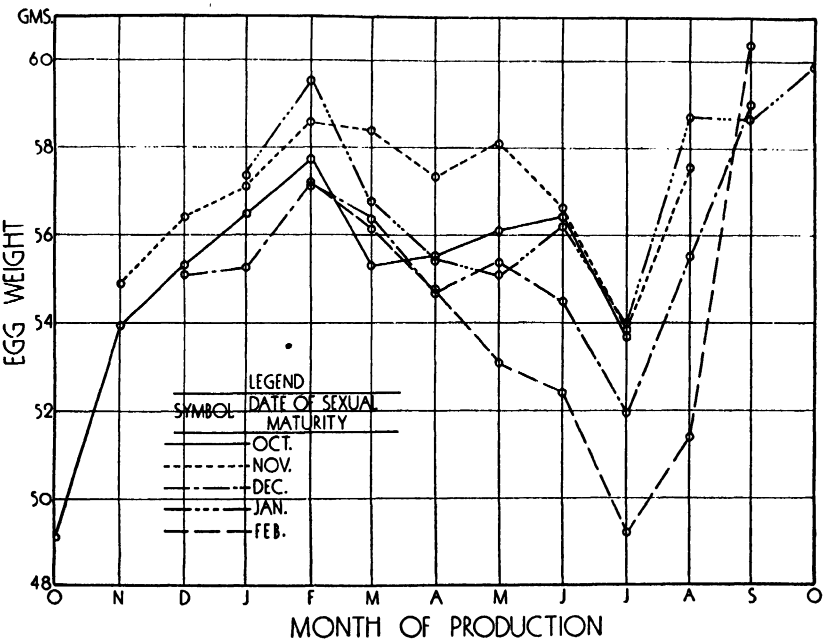


FIG. 43.—Showing the average egg weight per month in eggs laid by Rhode Island Red pullets, segregated according to the month that laying commenced. Maximum monthly egg weight was attained in February regardless of the month that laying commenced except for birds that continued laying until September and October. (*Funk and Kempster*, 1934.)

BREEDING FOR GOOD EGG SIZE, COLOR AND TEXTURE OF SHELL, AND INTERIOR QUALITY

The number of eggs laid is not the only criterion for determining the breeding worth of sires and dams. There are four other characteristics, of interest to consumers as well as producers, that should be taken into consideration in the development of breeding stock that will best meet the needs of the poultry industry. Housewives want for cooking and

baking purposes eggs that have the following four qualities: (1) good size, (2) uniform shell color, (3) sound shell texture, (4) good interior quality.

Selecting for Egg Size.—Egg size and egg weight are synonymous terms in so far as new-laid eggs are concerned; the larger the size the heavier the egg. In any given flock of pullets the size of egg is apt to vary a great deal because usually the smaller the bird the smaller the size of egg she is inclined to lay, and the earlier in life she begins laying usually the smaller the first eggs she lays. Also, in any given flock of pullets egg size tends to increase from the time that laying begins up to and including the month of February; it is extremely interesting to note that in the case of several different flocks including different breeds in different parts of the country maximum egg size during the first laying year has been obtained in the month of February. Moreover, it is also interesting to note that February is usually the month that maximum first-year egg size is obtained regardless of the age at sexual maturity or age in days that laying commenced.

TABLE 25.—THE AVERAGE WEIGHT OF THE FIRST 10 EGGS LAID AND THE AVERAGE WEIGHT OF ALL EGGS LAID FROM OCTOBER TO JUNE, RESPECTIVELY, IN RELATION TO THE BODY WEIGHT AT START OF LAYING, IN WHITE PLYMOUTH ROCKS
(Funk and Kempster, 1934)

Body weight at first egg, pounds	No. of birds	Average weight of first 10 eggs, grams[1]	Average egg weight October to June, grams[1]	Maximum monthly egg weight, grams[1]
3.6–4.5	21	47.8	54.9	56.8
4.6–5.5	44	52.4	55.2	57.5
5.6–6.5	49	54.8	56.6	58.4
6.6–7.5	8	58.3	59.7	61.2

[1] A 2-oz. egg weighs 56.7 g.

One apparent reason why pullets that begin to lay relatively early in life tend to lay smaller eggs than pullets that begin later in life is because usually the earlier in life that laying starts the smaller the body size.

Then again, pullets that have the smallest body weight throughout their first laying year tend to lay the smallest eggs.

It is apparent, therefore, that the body weight of the pullets has, on the average, a direct bearing on the size of egg laid. This becomes clear when it is realized that most pullets increase in body size up to and including February, during which time the size of egg laid has also been shown to increase. After February of the first laying year both body weight

TABLE 26.—AVERAGE WEIGHT OF FIRST 10 EGGS LAID AND AVERAGE WEIGHT OF ALL EGGS LAID FROM OCTOBER TO JUNE, RESPECTIVELY, IN RELATION TO THE AVERAGE BODY WEIGHT FROM OCTOBER TO JUNE, IN WHITE PLYMOUTH ROCKS
(Funk and Kempster, 1934)

Average body weight, pounds	No. birds	Average weight of first 10 eggs, grams[1]	Average egg weight October to June, grams[1]	Maximum monthly egg weight, grams[1]
3.6 to 4.5	10	49.3	52.7	54.5
4.6 to 5.5	65	52.2	55.4	57.9
5.6 to 6.5	40	54.5	56.8	58.9
6.6 to 7.5	7	56.7	58.7	60.7

[1] A 2-oz. egg weighs 56.7 g.

and egg size tend to decrease, the latter especially during the hot summer months. During the fall or winter months, as the birds are entering their second year of production, egg size tends to increase up to and including approximately the month of February. The mean size of eggs laid during the second year is usually somewhat larger than the mean size of eggs laid during the first year.

The problem of maintaining good egg size seems to be largely a problem of maintaining good body size, although there are other matters to be considered. It has been shown, for instance, that egg size tends to decrease as the number of eggs in a clutch increases but not proportionately so; in other words, there is approximately the same absolute decrease in egg size between the sixth and first eggs in a 6-egg clutch as between the second and first eggs in a 2-egg clutch. But a 2-egg-clutch hen is inclined to be a much poorer layer than a 6-egg-clutch hen, and the 2-egg-clutch hen is inclined to lay larger eggs on the average than a 6-egg-clutch hen. A 2-egg-clutch hen starts laying later in life than the 6-egg-clutch hen so that the problem of the poultry breeder is to develop a high laying strain of birds that have good body size when they begin laying. This should be accomplished by the progeny test in the same way as applied in developing high egg production. In order to determine the average size of egg laid by a bird during her first laying year, the weighing of eggs may be done on a given day each week throughout the bird's first laying year, or the weighing may be done on 4 consecutive days of each month of the first laying year, or the first 10 eggs laid by each bird during her fifth month of laying may be weighed.

A desirable goal would seem to be to have Leghorn pullets weighing at least 3½ lb. and Rhode Island Red, New Hampshire, Wyandotte, and Plymouth Rock pullets at least 5 lb. when they start laying in order to obtain an egg size approximating 24 oz. per dozen for the average egg size

of the first-year production. Good egg size and good egg production can be combined in the same strain provided proper selection of the breeding stock on the progeny-test basis is followed. In the development of a sound breeding program it is particularly important to select male breeders from among the families of high producers that lay eggs of good size.

Selecting for Shell Color and Texture.—The problem of securing uniformity of shell color is of greater importance in White Leghorns and other "white-egg" breeds than in "brown-egg" breeds. The average housewife has less objection to varying shades of brown in a dozen brown eggs than to a few tinted eggs in a dozen white ones. In some flocks of white-egg breeds quite a few of the birds may lay tinted eggs. By trapnesting, these offenders can be identified and eliminated from the flock. But that is not enough; the poultry breeder should go through his records and identify the sire and dam of the pullets laying the tinted eggs and not only remove the sire and dam from the breeding pen but avoid using any of their progeny as breeders. This is just one example of applying the progeny test in changing the breeding qualities of a strain of fowls.

Very little is known concerning the inheritance of shell texture, and for the most part, provided the diet is satisfactory, most flocks lay eggs that are reasonably sound in that respect. In case a number of birds in a flock are found to produce eggs with thin shells, resulting in excessive breakage, offenders should be located, and they, and all closely related birds likely to transmit the defect, should be removed from the flock.

Selecting for Interior Quality.—Since the percentage of thick white of the total white in eggs has been shown to be an inherited characteristic, it is apparent that by the adoption of a system of selecting breeding stock on the family basis it should be possible to develop a strain of birds noted for its ability to lay eggs having a high per cent thick white of total egg white.

THE RESPONSIBILITY OF THE POULTRY BREEDER

It may be taken for granted that, for the most part, superior breeding stock can be developed only by a class of superior poultry breeders. In fact, the greatest need of the poultry industry is greatly increased numbers of poultry breeders who not only know how to raise and manage chickens properly but have a sound knowledge of the more fundamental problems involved in the selection and mating of breeding stock. Superior breeding stock can be developed only through the adoption of a sound breeding program.

It must be a balanced program, combining high egg production, good rate of growth, good body size for the breed, efficient flesh production, eggs of good size and desirable interior quality, good fertility and hatchability, and low chick and pullet mortality. To accomplish these things with

any degree of success is a formidable task. Since inheritance plays such an important role in the development of these numerous characteristics, it becomes apparent that numerous matings are necessary, and the largest possible number of progeny should be kept to provide for the wisest selection of the most superior sons and daughters of the most superior sires and dams.

Poultry breeders must learn that the best breeders cannot be selected from their external appearance alone; it is the genes that count. For instance, the White Leghorn has white plumage because it carries a gene that prohibits the development of pigment. But the White Leghorn also carries the sex-linked gene for barring, as certain crosses have demonstrated. Now, the average White Leghorn breeder would not suspect the presence of the sex-linked gene for barring in his stock, but it is there just the same. Then, again, the White Plymouth Rock carries a gene for the extension of black pigment to all parts of its plumage, but the bird is white because it lacks a certain gene for the production of pigment. And so it is with all breeds and varieties; there is "more than meets the eye" in determining how a bird will breed. Breeding tests tell the tale.

The poultry breeder should know how to measure the results that he secures. Of course, he knows how to count and weigh eggs and weigh birds, but he must be able to do much more than that in order to make the most progress. It is the average results that are secured from large families obtained from each mating that serve as the best measure in selecting superior sires and dams. Moreover, the breeding stock and their progeny should be kept under as uniform conditions as possible from year to year.

The production record, the pedigree, the sisters' records, and the progeny test provide four means of identifying the dam of superior breeding worth. A superior sire is identified by the production record of his dam, his own pedigree, the average egg production of his full sisters, and the kind of progeny he produces. It can be said with a reasonable degree of certainty that in the present state of the poultry-breeding industry of the United States, the selection of breeding stock on the basis of the progeny test is by far the most important step in the development of a balanced breeding program.

Future progress in poultry-breeding work will depend on the kind of poultry breeders that carry on the work. The chicken presents the possibilities; upon the poultry breeders rest the responsibilities.

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CHAPTER V

INCUBATION PRINCIPLES AND PRACTICE

The reproduction of flocks from year to year for the purpose of replacing birds that have died or have been marketed after having passed their stage of usefulness has become a very much mechanized procedure as compared with the early days of American poultry culture. In the early days a few broody hens on each farm performed the work of incubating the eggs necessary to replenish the farm flock. With the commercial development of the poultry industry, including the production of several million broilers each year and the expansion of many egg-laying flocks containing several thousand birds each, the broody hen has been almost entirely crowded out of the picture by the modern incubator, which provides for the incubation of eggs by the million.

Despite the fact that the broody hen is more efficient, on the average, than the incubator from the standpoint of the number of chicks hatched from a given number of fertile eggs set, the incubation of eggs by artificial means became a necessity in order to supply the country with its enormous annual crop of chicks. Moreover, incubators have been improved upon very materially during recent years, although only about 70 per cent of the eggs that are set hatch into good chicks. In other words, out of every 100 eggs set, approximately 30 fail to hatch, owing to infertility, lack of hatching quality, or faulty methods of incubation. The fundamental principles of successful artificial incubation are of the utmost importance, therefore, if the flocks are to be reproduced most efficiently.

The Length of the Incubation Period.—The normal incubation period of the egg of the chicken is approximately 21 days, although chicks of the Leghorn and similar breeds usually hatch a few hours earlier than chicks of the heavier breeds, such as Plymouth Rock and Rhode Island Red, when the conditions of incubation for the eggs of the different breeds are identical.

In any given flock the largest eggs usually require a longer period of incubation than the smallest ones. The longer that hatching eggs are stored at room temperature before being incubated the longer is the time usually required for incubation. Eggs of highly inbred birds sometimes require as many as 12 hours longer for incubation than the eggs of birds of the same breed that are not inbred. The higher the temperature during incubation the more rapid the development of the embryo and the earlier the hatch.

STRUCTURAL DEVELOPMENT OF THE EMBRYO

The development of the chick from the egg is a phenomenon of unusual interest, inasmuch as the various processes involved therein are closely related to the more important factors affecting hatching results. For instance, the development of the embryo during incubation is affected by such factors as the length of time that the fully formed egg is held in the uterus before being laid, the position of the eggs during incubation, and the number of times that eggs are turned daily during the incubation period, as well as by the temperature, humidity, oxygen, and carbon dioxide content of the atmosphere of the incubation chamber.

The development of the chicken embryo during the period of incubation is analogous to the development of the mammalian embryo during the gestation period. The mammalian embryo is developed entirely within its mother's body, whereas the chicken embryo, although starting its development within its mother's body, develops mostly outside.

Development before Laying.—Approximately 3 hr. after the egg is fertilized in the oviduct, the germ spot, or reproductive cell, in the yolk divides into two cells. Cell division continues until a thin disk is formed. The cleavage process of the germinal disk continues and soon gives rise, through a process known as "gastrulation," to a structure having two layers of modified cells, the outer layer comprising the ectoderm and the inner layer the entoderm. At this stage of development the "blastoderm," as it is now called, is thinner and more transparent in its central portion, called the "area pellucida," and thicker around its margin, called the "area opaca," and is visible to the naked eye when a fertile egg is opened. The axis of the blastoderm lies at approximately right angles to the long axis of the egg. The cleavage process is arrested when the egg is laid but proceeds again when the egg is subjected to the proper temperature. If the temperature is below 68°F., the development of the embryo is completely arrested.

It has been demonstrated at the National Agricultural Research Center that fertile eggs can be distinguished from infertile eggs by candling methods, after about 15 hr. of incubation. Green or very dark blue glasses are a distinct aid in candling.

Development during Incubation.—When the egg is placed under proper conditions of incubation, the blastoderm develops rapidly, the primitive streak appearing in the area pellucida during the first 12 hr. of incubation. The blastoderm gradually extends over the surface of the yolk and gives rise to the formation of the embryo. The two-layered structure soon gives rise to a three-layered structure, the mesoderm arising between the ectoderm and the entoderm.

The ectoderm gives rise to the skin, feathers, and other external features as well as the nervous system. The mesoderm gives rise to

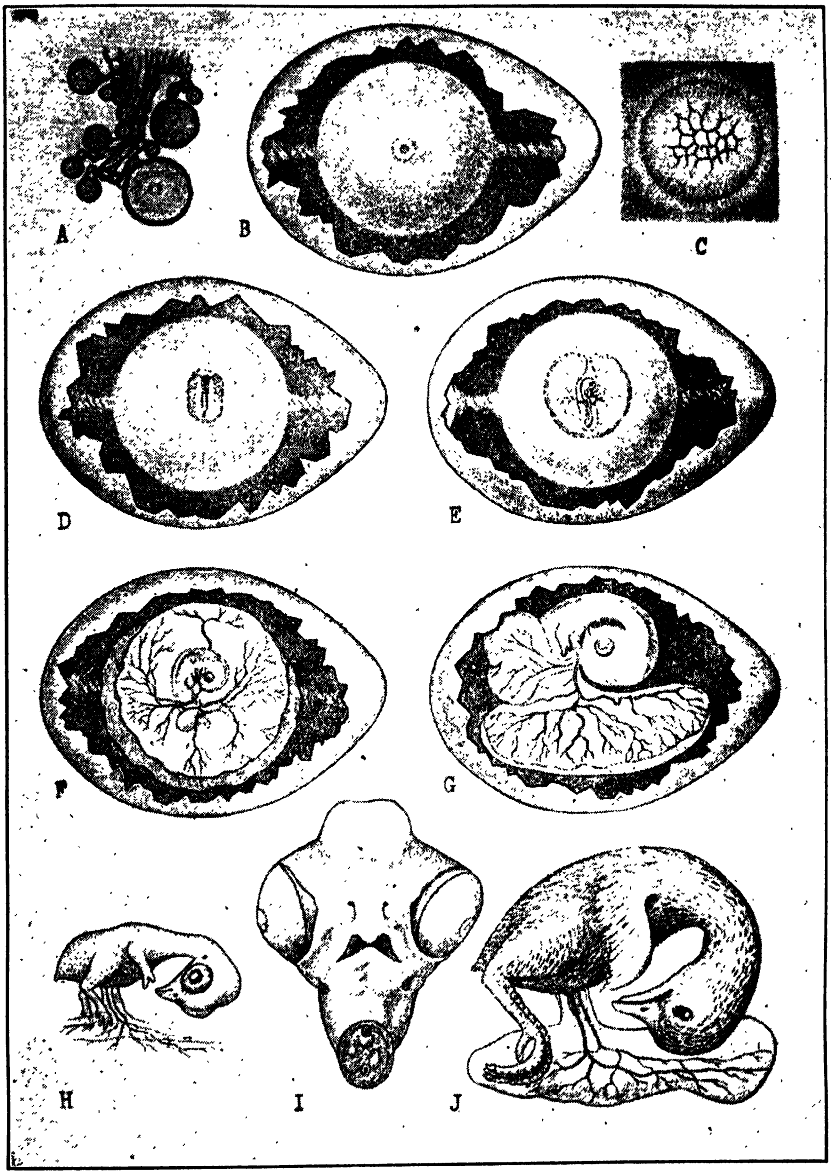
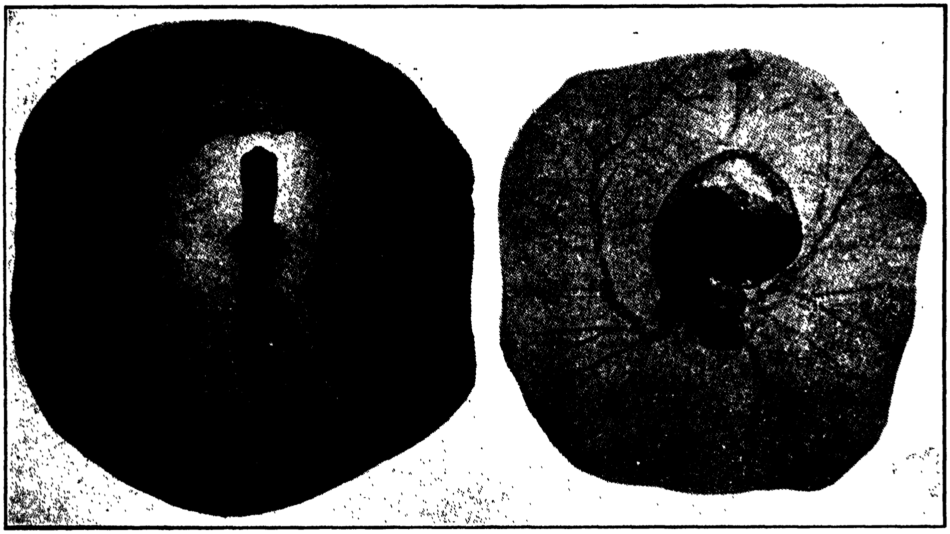


Fig. 44.—The development of the chick. *A*, part of the ovary showing ova in different stages of development. *B*, the fertilized egg at time of laying. *C*, early cleavage of the blastoderm. *D*, egg opened to show the late neural-fold stage and extension of blastoderm over yolk. *E* and *F*, stages during which the circulation is becoming established as the blastoderm extends further over the yolk. The allantois appears as a bladder-like outgrowth at the posterior end of the embryo in *F*. *G*, stage in which the allantois has enlarged and the yolk, surrounded by the yolk sac, has become reduced. In *F* and *G* the amnion is shown closely surrounding the embryo. *H*, later stage showing yolk stalk. *I*, front view of head, showing eyes, nasal openings, mouth, and ears. *J*, a stage shortly before hatching, showing yolk stalk and remains of yolk. (*Photograph by Curtis and Guthrie redrawn from Duval.*)[1]

[1] Curtis and Guthrie, "Text-book of General Zoology." By permission of John Wiley & Sons, Inc., publishers.

the bones, blood, muscles, and reproductive and excretory organs. The entoderm gives rise to the respiratory and secretory organs and the linings of the digestive tract.

As development proceeds, certain folds develop, surrounding the embryo so that it is enclosed in an inner membrane, called the "amnion," and an outer membrane, called the "chorion," each composed of ectoderm and mesoderm. The amnion contains a fluid in which the embryo is embedded, providing protection against mechanical shock and preventing adhesion of the embryo through the action of the muscular fibers in the wall of the amnion.



A B

FIG. 45.—*A*, embryo of 36 hours incubation. *B*, embryo of 90 hours incubation; note the well-defined allantois and blood vessels. (*After Evans.*)[1]

By this time there has developed from the posterior portion of the hind gut an outgrowth known as the "allantois," quite visible through the shell when the egg is tested on the seventh day of incubation. As the embryo increases in size, the allantois extends farther and farther until its outer surface comes into close contact with the inner surface of the chorion. As the amount of albumen of the egg becomes reduced, the allantois is closely applied to the inner surface of the chorion, which in turn lies against the shell membrane and shell, and thus becomes a respiratory and excretory organ by means of which oxygen and carbon dioxide are received and discharged. The allantois also absorbs albumen which serves as nourishment for the embryo.

By the fourteenth day of incubation the axis of the embryo is parallel with the axis of the egg so that when the chick is fully formed the head is

[1] EVANS, ERNEST, "The Biology of Birds." By permission of John Dixon, Ltd., publishers.

toward the large end of the egg. The albumen of the egg has been almost the sole source of nourishment for the embryo for the first 2 weeks, after which the yolk serves principally as the source of nourishment. The yolk, carried by the blood, is absorbed by portions of the walls of the yolk sac which surrounds the yolk, the latter being in direct connection with the embryo by means of the yolk stalk. The yolk sac enters the body of the embryo usually on the nineteenth and twentieth days, and the development of the chick is completed.

FIG. 46.—*C*, embryo of 8 days incubation. *D*, embryo of 11 days incubation seen from right side: *B*, beak; *C*, cloacal elevation; *E*, ear; *Ey*, eye; *L*, leg with toes complete; *S*, stalk of allantois; *T*, tongue; *Ta*, tail; *W*, *W*, wing. (*After Evans.*)[1]

At Hatching Time.—Up to hatching time respiration has taken place by means of the allantois, but when the beak is thrust into the air sac of the egg the lungs begin to function, and there is thus a marked change in the nature of the respiration. The beak, equipped with a horny cap on the upper mandible, pips a circle around the large end of the shell while the embryo revolves slowly within the shell. Two muscles in the neck of the chick, musculus biventor and musculus spinalis, are largely instrumental in enabling the chick to exert enough pressure with its beak to break through the shell.

The Completed Chick.—Twenty-one days have witnessed the transformation of the fertile egg into a fully formed chick, which leaves behind,

[1] EVANS, ERNEST, "The Biology of Birds." By permission of John Dixon, Ltd., publishers.

as remnants, the shell, the shell membranes, and the membranes of the allantois and chorion. In Table 27 are listed the principal events in the structural development of the embryo.

√TABLE 27.—PRINCIPAL EVENTS IN THE STRUCTURAL DEVELOPMENT OF THE EMBRYO (Romanoff, 1931)

Before egg laying	Division and growth of living cells; segregation of cells into groups of special function (germ layers)
Between laying and incubation	No growth; stage of inactive embryonic life
During incubation:	
1st day:	
16 hr	First sign of resemblance to a chick embryo
18 hr	Appearance of alimentary tract
20 hr	Appearance of vertebral column
21 hr	Beginning of formation of nervous system
22 hr	Beginning of formation of head
24 hr	Beginning of formation of eye
2nd day:	
25 hr	Beginning of formation of heart
35 hr	Beginning of formation of ear
42 hr	Heart begins to beat
3rd day:	
60 hr	Beginning of formation of nose
62 hr	Beginning of formation of legs
64 hr	Beginning of formation of wings
4th day	Beginning of formation of tongue
5th day	Formation of reproductive organs and differentiation of sex
6th day	Beginning of formation of beak
8th day	Beginning of formation of feathers
10th day	Beginning of hardening of beak
13th day	Appearance of scales and claws
14th day	Embryo gets position suitable for breaking the shell
16th day	Scales, claws, and beak becoming firm and horny
17th day	Beak turns toward air cell
19th day	Yolk sac begins to enter body cavity
20th day	Yolk sac completely drawn into body cavity
	Embryo occupies practically all the space within the egg except the air cell
21st day	Hatching of chick

Although the development of the embryo has taken place entirely within the shell of the egg, which has sometimes been referred to as a closed system, the embryo must obtain an adequate supply of oxygen from outside the egg in order to develop properly. Moreover, during the period of incubation the egg loses water, and the developing embryo liberates carbon dioxide through the porous shell. These processes are associated with the various physiological changes that take place in the growth and development of the embryo.

THE PHYSIOLOGY OF EMBRYO DEVELOPMENT

During the incubation of fertile eggs the white increases in viscosity, while, in the yolk, viscosity decreases rapidly till the fifth day, after which it rises until the end of incubation. The yolk gains in water at the expense of the white.

At the beginning of incubation the yolk is acid; but as incubation proceeds, the yolk becomes alkaline, with a sudden temporary drop at the sixteenth day, according to work done at Cornell University. At the same institution it was found that the white reaches its highest peak of alkalinity at about 2 days of incubation, thereafter gradually changing to become neutral. The trend toward acidity on the part of the white is of significance in relation to the increased production of carbon dioxide by the embryo as development proceeds.

The Respiration of the Developing Embryo.—It has long since been determined that the developing embryo gives off carbon dioxide and takes in oxygen. The embryo respires long before the development of the chick's lungs.

The air space, usually formed in the large end of the egg, serves an important function in respiration. Among the early investigators the general conclusion was that aqueous transpiration took place over all parts of the egg but that gaseous exchange took place only by way of the allantoic membrane and the air space. The results of various workers go to show that the embryo will develop normally if the entire egg, except the upper part containing the air space, is coated with a varnish or with water glass and that as much as one-half of the shell, including the air space, may be coated without apparently affecting normal development. The results of research conducted at the National Agricultural Research Center have demonstrated that by coating the large end of the egg with paraffin, in eggs incubated large end up, the percentage of chicks hatched was greatly reduced as compared with untreated eggs and the percentage of chicks with their heads in the small end of the egg was greatly increased.

Increase in Carbon Dioxide Elimination.—The results secured by various investigators have shown that, whereas the carbon dioxide (CO_2) in the air space of the egg increases only four or five times during incubation, the carbon dioxide produced by the embryo increases about forty times. In this connection it is interesting to note that the shell and the shell membrane above the air space become progressively more permeable as embryonic development proceeds. The elimination of carbon dioxide decreases from the first to about the third day of incubation, after which the amount eliminated is proportional to the weight of the embryo.

Oxygen Requirements Increase.—As the embryo develops, the amount of oxygen required increases. The ratio of the carbon dioxide given off

to oxygen consumed is known as the "respiratory quotient." Recent research has shown that for the first 2 days of incubation the respiratory

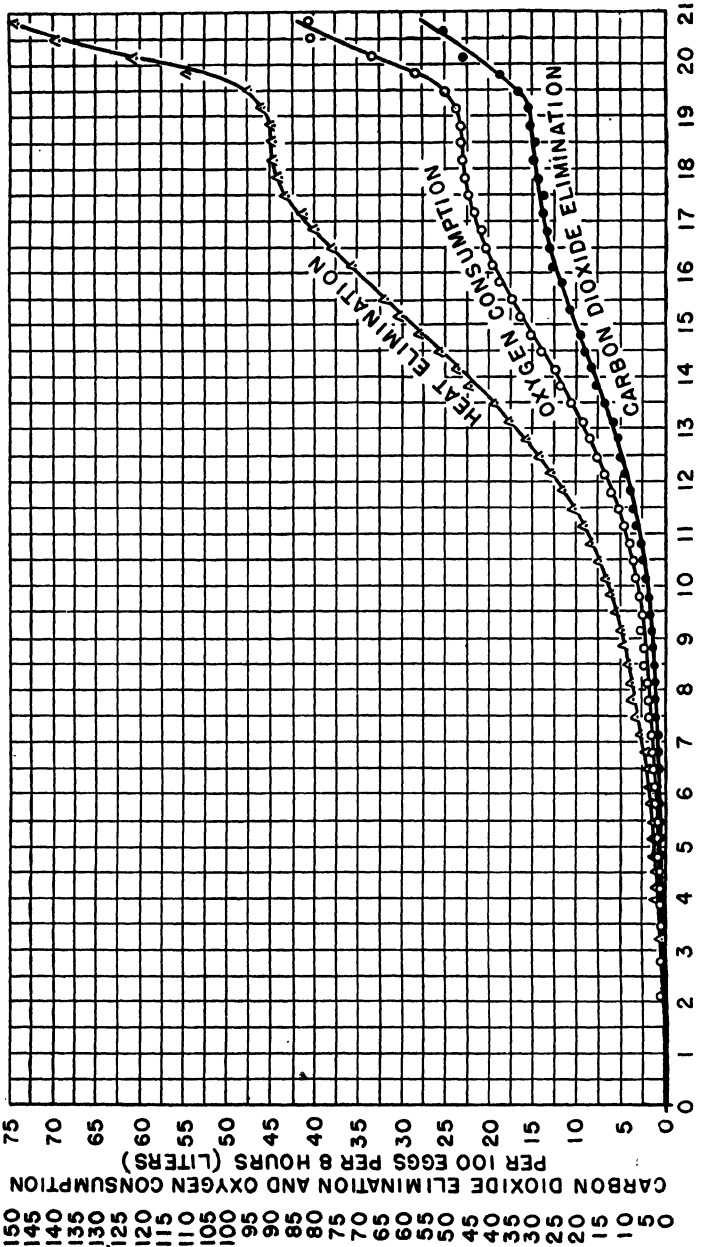


FIG. 47.—Energy metabolism of the chick embryo at optimum conditions of incubation (temperature 100°F., relative humidity 60 per cent, oxygen 21 per cent, and carbon dioxide below 0.5 per cent). (*Barott*, 1937.)

quotient is about 1.00, after which it declines to about 0.70 on the tenth day, thereafter remaining constant.

An insufficient supply of oxygen either kills the embryo in the early stages of development or produces abnormal chicks. Eggs incubated in

an atmosphere containing from 10 to 15 per cent oxygen produced embryos that lived for about 72 hr. only, and the embryos were abnormal. This is quite interesting in view of the fact that the atmosphere ordinarily contains approximately 21 per cent of oxygen. The most recently published results by the National Agricultural Research Center show that the atmosphere of the egg chamber should contain approximately 21 per cent of oxygen in order to secure best results in hatching.

The Metabolism of the Developing Embryo.—Among the physiological changes occurring during embryonic development probably the most important are those which take place in the utilization by the developing embryo of the different substances contained in the egg. The egg is composed of carbohydrates, fat, protein, and minerals, and the shell is composed largely of calcium. These substances are utilized by the embryo during its development but at different rates during development, as shown by the results of various workers.

The developing embryo secures its energy from three successive sources: carbohydrates; then proteins; and, lastly, fat. These elements serve as sources of energy.

Carbohydrate Metabolism.—Carbohydrate metabolism has its chief importance at the beginning of development, when the various organs of the embryo are taking shape. There appears to be a close correlation between the utilization of sugar by the embryo and its respiratory quotient during the first 5 days. The metabolism of carbohydrates in the chick embryo is summarized in the following brief account from the research results obtained at the University of Cambridge, England.

During the first week of incubation the amount of free sugar in the egg decreases equally in the white and in the yolk. On the ninth day the white is entirely deprived of free sugar, while the yolk has lost only half its original amount.

In the whole egg the amount of glycogen increases continually during incubation; in the embryo this process takes place only after the eleventh day, resulting in an actual decrease of glycogen content in the white and in the yolk after the thirteenth day. This indicates the existence in the chick of a "transitory liver" possessing a glycogenetic function analogous to that of the placenta of mammals, a function that comes into play when the chick has reached halfway in its development.

The total glucose of the whole egg decreases up till the seventh day, then increases until the eleventh, when it again decreases. This increase in carbohydrates between the seventh and the eleventh day corresponds to a loss of fats, which do not suffer combustion but are transformed in the embryo into carbohydrates.

During the earliest stages of development there is present a large proportion of glucose, neither free nor in the form of glycogen but com-

bined with the proteins (mucoproteins); this explains the presence in young embryos of "primitive connective tissue."

The curve of the free-sugar ratio in the embryo rises until the eleventh day and then proceeds to fall; at this moment the glycogen ratio also undergoes a rapid change. Insulin starts to be secreted round about the tenth day of incubation.

Protein Metabolism.—There are four different kinds of protein in the albumen and three different kinds of protein in the yolk of the egg. During the last week of embryonic development there is a certain current of protein into the yolk, and this is also true of water. Enzymes are probably contained in both albumen and yolk, and their activity increases as incubation proceeds. The enzymes break down the proteins and prepare them for embryonic nourishment. Uric acid accumulates up to the time of hatching, indicating the continuous oxidation of protein.

Fat Metabolism.—The utilization of the fat of the egg by the developing embryo has been investigated, and it is apparent that fat is the most important source of energy. The metabolism of fat takes place principally after the eleventh day. The rate of the metabolism of fat, according to the results secured at the University of Edinburgh, is apparently controlled by the increase in the weight of the liver, which is very small up to the fourteenth day, after which it rapidly increases in size. The results of research on fat metabolism at Cornell University show that the curve of consumed fat is quite similar to the curve of the rate of the growth of the embryo.

Mineral Metabolism.—The utilization by the embryo of the various minerals contained in the egg and in the shell has been studied by a number of workers, particularly in respect to phosphorus and calcium. The utilization of phosphorus is a very complicated problem because six different forms of phosphorus are involved. Briefly, it may be said that the greatest changes in phosphorus metabolism occur after the fifteenth day of incubation and that apparently phosphorus utilization by the embryo is associated with the calcification of bone. Concerning the utilization of calcium, all investigators report a large increase of calcium in the embryo and a loss of it from the shell, the calcium in the shell being broken down more readily in the presence of carbon dioxide. Approximately 75 per cent of the calcium of the newly hatched chick comes from the shell during the process of incubation.

Efficiency of Metabolism.—As the embryo grows there is an increasing percentage of solid matter in it. At the beginning of the incubation period the embryo constitutes an insignificant part of the total living tissue, the greatest part being the yolk.

As observed previously, the respiratory quotient is the ratio of liters of carbon dioxide eliminated by the embryo to the liters of oxygen consumed. The thermal quotient is the ratio of calories of heat eliminated

by the embryo to the grams of carbon dioxide eliminated. Carbohydrate metabolism is represented by a respiratory quotient of 1.00 and a thermal quotient of 2.57; fat metabolism is represented by a respiratory quotient of 0.71 and a thermal quotient of 3.35; protein metabolism gives practically the same respiratory and thermal quotients as fat.

Although the developing embryo obtains its energy for the most part first from the carbohydrates, then from the proteins, and lastly from the fats, it should be understood that there is some overlapping. The efficiency with which the developing embryo transforms the yolk and white into embryonic tissue appears to be the lowest between the seventh and tenth days of incubation, according to results secured at the University of Edinburgh, for it has been shown that during that period the ratio of dry matter stored in the embryo to dry matter oxidized is lower than at other periods of incubation.

The embryo is able to store about 98 per cent of the proteins available, about 82 per cent of the carbohydrates, and about 43 per cent of the fat. The efficiency of the metabolism of the three elements combined for the whole of the embryo's development is about 68 per cent.

Embryo Mortality and Its Causes.—In some flocks a few hens may be observed that have a 100 per cent hatching record for the entire breeding season. In such cases three important observations are worthy of note: (1) Hens with a hatchability record of 100 per cent are superior individuals which possess the genetic constitution for high hatchability; (2) the conditions of incubation were apparently satisfactory; (3) the eggs laid by the other members of the flock must have been deficient in certain respects which resulted in the embryos' dying some time during the incubation period. That hens differ genetically in their ability to produce eggs of good hatching quality has already been demonstrated in a previous chapter. Certain it is that the genetic constitution of the breeding stock is an important factor in relation to embryo mortality among the eggs they produce.

That the diet which the breeding stock receives sometimes increases embryo mortality is demonstrated in a later chapter.

Faulty methods of incubation, of course, usually result in relatively high embryo mortality.

On the other hand, among the eggs laid by practically all flocks that have been bred and fed for high hatchability and where satisfactory conditions of incubation prevail, there is usually some embryo mortality. As a matter of fact, a hatchability of 80 per cent of all eggs set is regarded as very satisfactory, showing that under what may be termed the best of conditions embryo mortality amounts to 20 per cent.

Critical Periods in Embryo Development.—It has been found that approximately 65 per cent of the total embryo mortality occurs, for the most part, at two periods of incubation. The curves in Fig. 48 show that

the first period of relatively high embryo mortality includes the second, third, and fourth days of incubation, and the second period from the eighteenth to the twenty-first days. Apparently, these two periods of relatively high embryo mortality are associated with certain physiological processes that take place during embryo development.

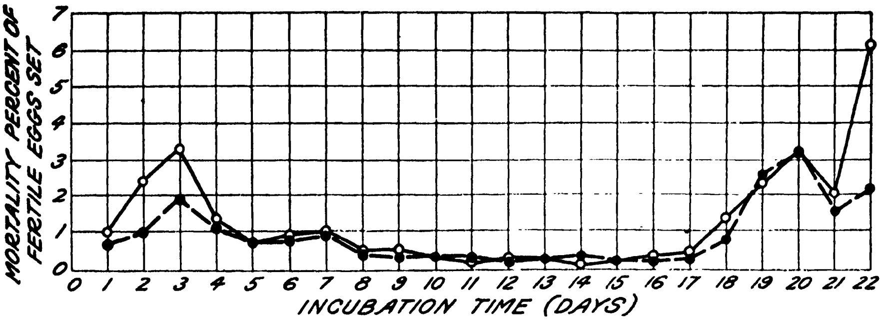


FIG. 48.—Showing embryonic mortality in eggs laid by Single-comb White Leghorns, and Single-comb Rhode Island Reds, ●. (*Byerly, Knox, and Jull*, 1934.)

It is interesting to note, for instance, that the rates of growth and gross form development change rapidly during the early stages of incubation, while the concentration of solids and chemical differentiation change mostly during the last half of the incubation period. The fact that lactic

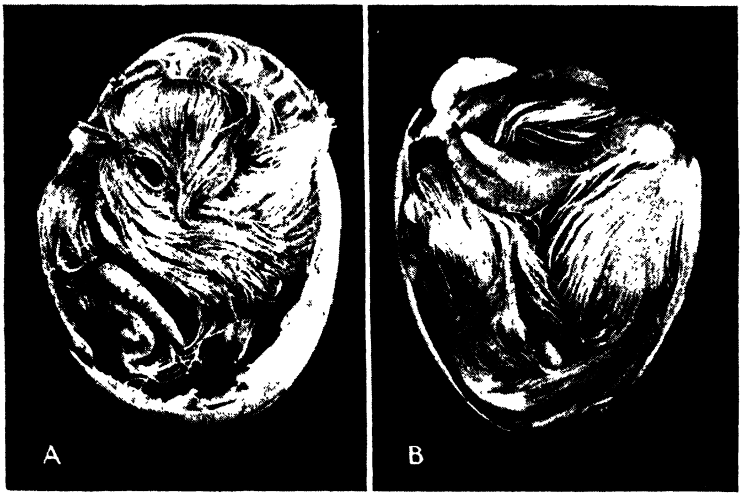


FIG. 49.—Fully formed chicks which failed to hatch: *A*, Normal position, the head under the right wing and the beak just entering the air cell; *B*, the embryo completely reversed with the head in the small end of the egg. (*Cavers and Hutt*, 1934.)

acid production reaches a peak on the fourth day may also have some bearing on early embryo mortality.

There are apparently four cycles of growth during embryo development, according to recent research conducted at Cornell University and the Missouri Experiment Station. The first cycle of growth continues

from the first to about the fourth day, the second cycle from the fourth to about the seventh day, the third from the seventh to about the seventeenth day, the fourth from the seventeenth to about the nineteenth day.

Embryo Position and Mortality.—The normal position of the embryo at hatching time is with the head toward the larger end of the egg with the neck bent sufficiently to bring the head to the right side of the body and the beak under the right wing, the tip of the beak pointing toward the air cell; the legs are on the ventral side of the embryo with the feet folded so that the toes reach the head.

TABLE 28.—CODE FOR THE CLASSIFICATION OF CHICK-EMBRYO POSITIONS, INCLUDING A CODE FOR THE ORIENTATION OF THE EMBRYO IN RESPECT TO THE EGG AXIS AND THE AIR CELL, BASED ON FOUR INDEPENDENT EVENTS (Dove, 1935)

A, air cell	*B*, body position	*C*, position of head and beak and direction of neck twist			*D*, proximity of beak to air cell
		Head	Beak	Primary twist in neck	
1, in base	*a*, head in base	0, between legs, feet over head	Straight down	None	*a*, beak near air cell
2, in tip	*b*, head in tip	1, to center between legs	Straight down	None	*b*, beak away from air cell (1 in. or more)
3, at side	*c*, head and feet in tip	2, to center between legs	Tip to right		
	d, head and feet in base	3, to center between legs	Tip to left		
		4, across breast	Points to right	Sinistral	
		5, across breast	Points to left	Dextral	
		6, to right side	To right, tip under right wing	Sinistral	
		7, to left side	To left, tip under left wing	Dextral	
		8, to right side	To right, tip under and over right wing	Sinistral	
		9, to left side	To left, tip under and over left wing	Dextral	
		10, to right side	To right, tip over right wing	Sinistral	
		11, to left side	To left, tip over left wing	Dextral	
		12, on right side	To front and left	Dextral	
		13, on left side	To front and right	Sinistral	
		14, on right side	To back or above	Right torticollis	
		15, on left side	To back and above	Left torticollis	
		16, to front	To front and above	S curve forward and upward	
		17, to back (above and over)	To back (above and over)	Retrocollis	

It has been found, however, that embryos may assume numerous modifications of the normal position without materially affecting hatchability. Embryo mortality is sometimes due to (1) air hunger on the part of the embryo due to the misplacement of the air cell, (2) gravity when the egg is incubated small end up, (3) factors of incubation or other factors causing delayed embryo development previous to the fifteenth day of incubation. A large portion of the dead-in-shell embryos is apparently due to defective embryos and those in which development has been delayed, according to recent investigations conducted at the Maine Agricultural Experiment Station. In other words, the position of the embryo in the egg is not in itself a criterion as to whether or not the chick could hatch but is a manifestation of the result of poor breeding, improperly balanced diets given the breeding stock, or faulty methods of incubation. The information in Table 28 shows the variations in position that embryos assume in the course of development.

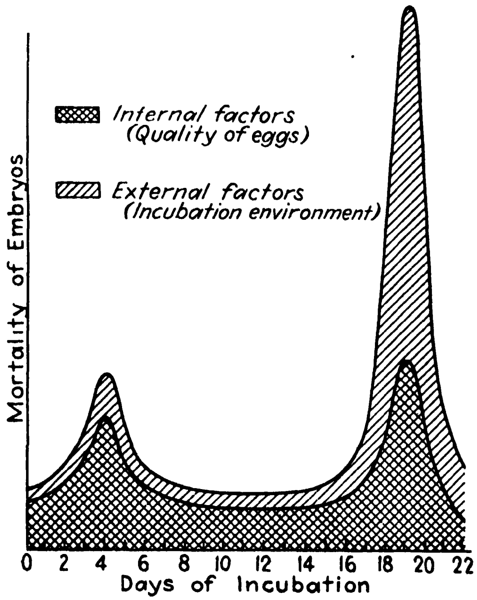


FIG. 50.—Causes of embryonic mortality in artificial incubation. The internal factors (quality of eggs) exercise an influence throughout the incubation period, the effects being more pronounced during the early and late periods of incubation than at other times. The external factors (incubation environment) exercise their greatest influence during the latter part of the incubation period. (*Romanoff*, 1931.)

PHYSICAL FACTORS GOVERNING SUCCESSFUL INCUBATION

The more fundamental aspects of the structural and physiological development of the embryo having been discussed, it now remains to consider the optimum conditions of incubation that should prevail in order to secure the largest possible number of good chicks in proportion to the number of eggs incubated.

The relative significance of internal factors, or qualities of the egg itself, and external factors, or conditions of incubation, as causes of embryonic mortality is graphically shown in Fig. 50. From this it is apparent that the incubation environment, or conditions of incubation, is on the average a very important factor in causing relatively high embryo mortality during the last 3 days of incubation. The more important conditions of incubation affecting hatching results include: (1) position and turning of eggs; (2) temperature requirements; (3) ventilation requirements, particularly with respect to the elimination of car-

bon dioxide and the available supply of oxygen; and (4) humidity requirements.

Position and Turning of Eggs.—In the natural incubation of eggs under hens it has been observed that she turns her eggs by lateral movements of the body as she nestles upon the eggs and by reaching under her body to move the eggs around with her beak. She turns her eggs with her beak day and night, and it has been observed that the eggs are rotated completely as many as ten times in two hours. Moreover, since the hen's nest is concave, the eggs tend to lie in an oblique position with the large end tilted slightly upward.

In artificial incubation the eggs are placed on the trays in an oblique position large end up for two reasons: (1) It has been observed that eggs incubated large end up are much more inclined to have the embryo develop with its head in the large end of the egg than when the eggs are placed small end up, and (2) placing the eggs large end up rather than flat allows more eggs to be incubated at one setting.

Research work at the National Agricultural Research Center has demonstrated that among eggs incubated large end up approximately 2 per cent of them contained embryos with their heads in the small end of the egg, whereas among eggs incubated small end up approximately 60 per cent of them contained embryos with their heads in the small end, many of which failed to hatch. It was also shown that the position of the embryo with its head toward the small end of the egg is determined during the second week of incubation.

Frequent turning of the eggs during incubation is desirable in order to prevent the embryo from adhering to the shell membrane, especially in the early stages of incubation, and to prevent any adhesion between yolk and allantois in the later stages of incubation. The results of research at a number of experiment stations show clearly that turning eggs as many as eight times daily gives better results, on the average, than turning twice daily. It has also been shown that it is much more important to turn eggs frequently during the first half of the incubation period than during the second half. From a practical standpoint, the turning should be done as early as possible in the morning and as late as possible at night, with several turnings between times during the first half of the incubation period.

Temperature Requirements.—Because of the relative importance of proper temperature in the incubation of eggs, much research has been conducted for the purpose of determining the temperatures that prevail in the natural incubation of eggs and to determine the optimum temperature and the effect of variations in temperature in the artificial incubation of eggs. A review of the literature reveals the fact, however, that numerous research workers apparently overlooked the fact that the optimum

temperature for successful artificial incubation is to some extent dependent upon the humidity of the air in the egg chamber and upon the rate of air circulation. In some cases the importance of the exact location of the thermometer in the egg chamber was not fully appreciated.

Since many of the results on incubation temperatures are reported in terms of degrees centigrade, it is advisable to mention here, for the sake of those consulting such results, that the Fahrenheit temperature is obtained by multiplying the centigrade temperature by 1.8 and adding 32 to the product. Thus, 40°C. = 104°F. In this book incubation temperatures are discussed in terms of degrees Fahrenheit.

Concerning the temperatures that prevail during natural incubation, the more general conclusions to be drawn from the observations made by

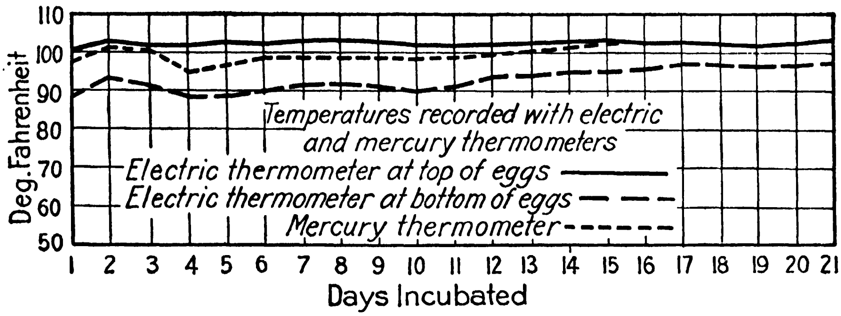


FIG. 51.—The average range in temperature at the top and at the bottom of eggs incubated in a non-forced-draft incubator. (*After Burke*, 1925.)

the various investigators are: (1) The surface temperature of sitting hens rises about 3.0°F. during the first week of incubation and remains fairly constant thereafter; (2) the temperature of the nest tends to increase slightly and steadily during the incubation period; (3) the temperature at the top of the egg tends to remain fairly constant, averaging 102 to 103°F., during the incubation period; (4) the temperature at the bottom of the egg is approximately 15.0 to 18.0°F. lower than the temperature of the top of the egg at the beginning of the incubation period, but this difference decreases as incubation proceeds, so that toward the end of the incubation period the temperature at the bottom of the egg is approximately 9.0 to 13.0° lower than the temperature of the top of the egg; (5) the temperature at the bottom of the egg tends to rise by probably 6.0 to 9.0°F. from the first to the sixteenth days and then falls about 2.0°F. from the seventeenth to the twentieth days.

The various observations made concerning temperature conditions under natural methods of incubation are of particular value with respect to their possible application to artificial incubation. Incubators of many different types have been devised so that it has become necessary to determine optimum temperatures for incubation purposes in the different

types. From the standpoint of temperature requirements, the various types of incubators may be divided into two groups: (1) incubators in which warm air is conducted to the top of the egg chamber and diffuses downward over the eggs or the eggs are heated by radiation from the heat supplied by pipes of warm water; (2) incubators in which the egg chamber is heated by mechanically forced circulation of air which is heated by electrical elements.

By far the most of the research work on temperature requirements in artificial incubation has been conducted in incubators of the first group. The general conclusion of the numerous lines of research work conducted during the past 25 years is that during the first 2 weeks of the incubation period the temperature on a level with the top of the eggs should be 101.5°F. and that during the last week the temperature at the same location should be 102.5°F.

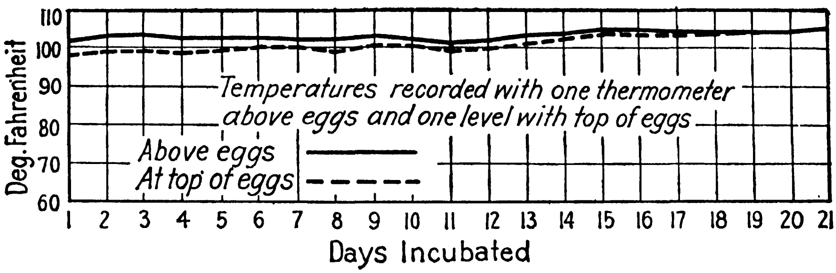


FIG. 52.—The average range in temperature at ½ in. above eggs and at top of eggs incubated in a non-forced-draft incubator. (*After Burke*, 1925.)

The results of research on the temperature requirements in incubators heated by mechanically forced circulation of air indicate that 100°F. is the optimum temperature. At the National Agricultural Research Center a series of tests was conducted at temperatures of 96, 98, 99, 100, 102, and 103.5°, the relative humidity in all tests being kept at 60 per cent, the concentration of oxygen at 21 per cent, and the concentration of carbon dioxide below 0.5 per cent. In all tests the air movement past the eggs was approximately 12 cm. per minute, and it should be observed the temperature at the bottom and the top of the egg was the same. The best hatches were secured at a temperature of 100°F. Deviations in temperature above and below 100°F. resulted in lowered hatches until at 96 and 103.5°, respectively, nearly all of the embryos died in the shell.

It remains to be determined whether or not better hatching results might be secured if temperatures of 99.5°F. for the first half and 100.5°F. for the second half of the incubation period were maintained or some other temperatures for different periods of incubation than maintaining a temperature of 100°F. throughout the entire hatching period.

Excessively high temperatures give rise to an increase in the rate of growth of the embryo, resulting in an increase in the liberation of carbon

dioxide, and there is a marked tendency for the embryos to assume abnormal positions within the egg. If relatively high temperatures are maintained for too long a period, embryo mortality is certain to be excessive.

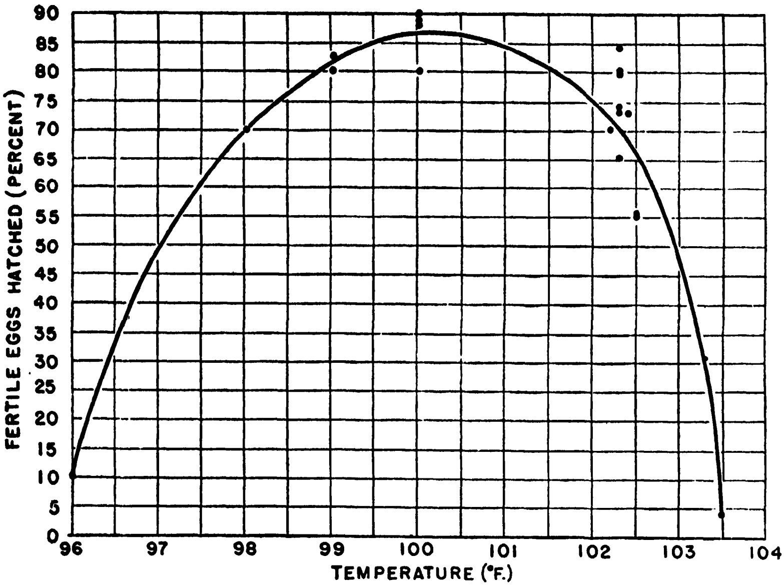


FIG. 53.—Effect of temperature of incubation on percentage of fertile eggs hatched (relative humidity 60 per cent, oxygen 21 per cent, carbon dioxide below 0.5 per cent). (*Barott*, 1937.)

The data in Table 29 show that eggs incubated at a temperature of 104.0°F. had an excessively high embryo mortality, especially on the nineteenth to twentieth day of incubation.

TABLE 29.—EFFECT OF TEMPERATURE ON EMBRYO MORTALITY
(Data of Romanoff and Faber, 1933)

Incubation age, days	Mortality expressed as a per cent of eggs remaining in the incubator				
	104.0°F.	100.4°F.	96.8°F.	93.2°F.	89.6°F.
16 to 17	5.71	1.41	0.00	0.00	0.00
17 to 18	15.15	0.00	0.00	0.00	0.00
18 to 19	15.38	8.19	0.00	0.00	0.00
19 to 20	60.00	19.29	21.43	0.00	0.00
20 to 21	33.33	10.42	12.12	14.71	0.00
21 to 22	.....	.....	.....	17.39	9.09

Excessively low temperatures cause a retardation in embryo development, accompanied by a diminution of carbon dioxide output. Especially during the first 2 or 3 days of the incubation period are excessively low temperatures liable to cause the death of the embryo.

The practice of cooling eggs for a few minutes each day of incubation, although practiced to a considerable extent for several years, has been found to be inadvisable.

Ventilation Requirements.—The proper ventilation of the incubator chamber during the incubation of eggs is necessary because as the embryo develops it requires oxygen, and it liberates more carbon dioxide, most of which must be removed from the incubator chamber.

The embryo breathes long before the formation of lungs, the oxygen absorbed and the carbon dioxide eliminated passing through the porous shell. In a series of experiments conducted at the National Agricultural Research Center, it was found that the best hatches were obtained when the carbon dioxide content of the egg chamber was kept at 0.5 per cent throughout the period of incubation. It was further found that the

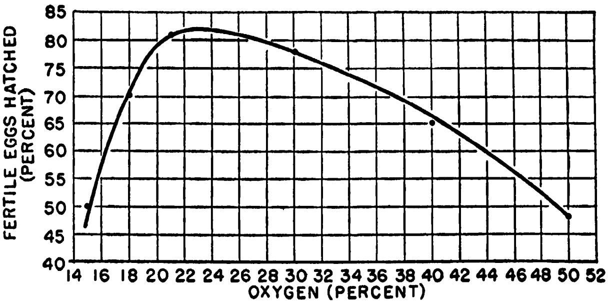


FIG. 54.—Effect of oxygen during incubation on percentage of fertile eggs hatched (temperature 99° F., relative humidity 70 per cent, carbon dioxide below 0.5 per cent). (*Barott*, 1937.)

decrease in the hatch was proportional to the increase in the carbon dioxide content of the egg chamber. It is obvious, therefore, that the ventilation of the incubator chamber must be such that the carbon dioxide eliminated by the embryos will be removed fast enough so that the carbon dioxide content of the atmosphere of the egg chamber does not exceed 0.5 per cent.

Since the developing embryo requires oxygen, it is obvious that the ventilating device of the incubator must be so designed as to supply adequate amounts throughout the period of incubation. The results of research on oxygen requirements conducted at Cornell University and at the National Agricultural Research Center have demonstrated that the atmosphere of the egg chamber should contain 21 per cent of oxygen, which is the oxygen content of normal air. At the latter institution it was found that each per cent decrease below 21 per cent in the oxygen content of the atmosphere of the egg chamber reduced the hatch by approximately 5 per cent. For each per cent increase in the oxygen concentration the hatch was reduced approximately 1 per cent. There-

fore, a deficiency in oxygen supply is relatively much more harmful than an excess.

Humidity Requirements.—During incubation the eggs lose weight, a large part of which is due to loss in water content. The amount of water eliminated has been found to be very largely proportional to the humidity of the atmosphere of the egg chamber.

Research work has demonstrated that it is the relative rather than the absolute humidity of the atmosphere of the egg chamber that affects hatching results. Relative humidity refers to the ratio between the

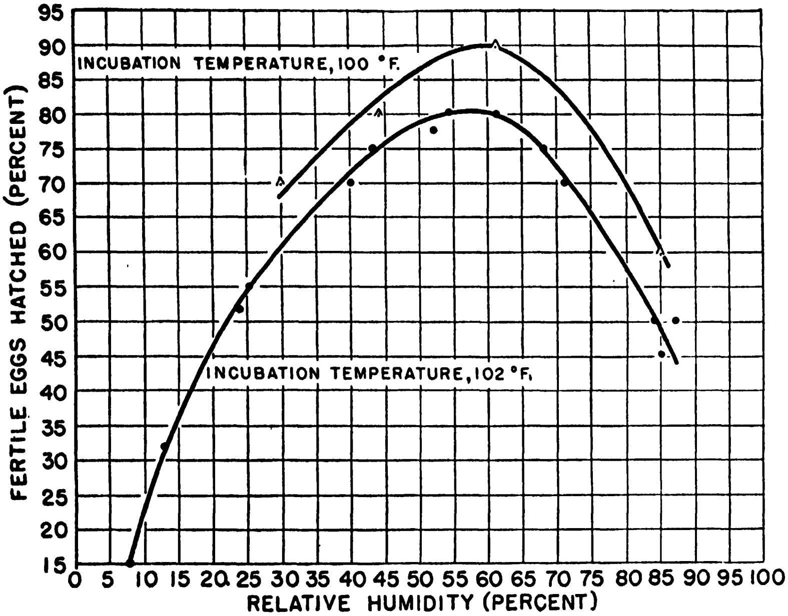


FIG. 55.—Effect of relative humidity during incubation at two different temperatures on percentage of fertile eggs hatched (oxygen 21 per cent, carbon dioxide below 0.5 per cent). (*Barott*, 1937.)

amount of water vapor actually contained in the atmosphere at a given temperature and the amount of vapor the atmosphere is capable of holding at the same temperature. It is well known, of course, that the capacity of air to absorb and hold moisture increases as its temperature rises; at 50°F., 1,000 cu. ft. of air is capable of holding 0.587 lb. of water vapor, whereas at 100° the same amount of air is capable of holding 2.851 lb. of water vapor. If it should be found that at 100°, 1,000 cu. ft. of air contains 1.711 lb. of water vapor, which is 60 per cent of what it is capable of holding at that temperature, the relative humidity would be 60 per cent.

Research work at Cornell University and the National Agricultural Research Center has demonstrated that the best hatches were obtained

when the relative humidity of the atmosphere of the egg chamber was maintained at very near 60 per cent relative humidity.

Optimum Conditions for Incubation.—The optimum conditions for the successful incubation of eggs may be summarized as follows: (1) For section-type incubators, which do not have mechanically forced circulation of the air in the egg chamber, the temperature on a level with the top of the eggs should be 101.5° during the first half of the incubation period and 102.5° during the last half of the incubation period; (2) for cabinet-type incubators, equipped for the mechanically forced circulation of air, the temperature should be 100.0° throughout the period of incubation; (3) for all types of incubators the ventilation should be such as to maintain an atmosphere in the egg chamber containing 21 per cent oxygen and not over 0.5 per cent carbon dioxide; (4) in all incubators a relative humidity of 60 per cent should be maintained in the atmosphere of the egg chamber throughout the period of incubation.

The successful incubation of eggs to produce the largest possible number of good chicks in proportion to the number of eggs incubated depends not only upon providing optimum conditions of incubation but also upon the selection and care of the eggs intended for incubation. Granted, however, that the selection and care of the hatching eggs have been such that the best possible hatching results can be secured, it is still important to bear in mind that certain things are necessary besides merely providing optimum physical conditions of incubation in the incubator in order to secure satisfactory hatches year after year. Such factors as the location of the incubator, its proper disinfection, and the proper care of incubator equipment all have a bearing upon successful incubation practice.

THE SELECTION AND CARE OF HATCHING EGGS

The careful selection of eggs for hatching purposes is a very important matter because the kind of egg incubated determines, to a large extent, the quality of chicks hatched. Fertile eggs of good hatching quality are necessary for good hatches. All eggs for hatching should be uniform in shape and size and sound in shell.

Egg Size Important.—The size of the eggs used for hatching is very important because there is a high correlation between the size of eggs used and the size of chicks hatched. Furthermore, the continued use of small eggs for hatching purposes would soon result in reducing the average size of the birds in a flock, as well as decrease in the size of eggs shipped to market. The most careful attention, therefore, should be given to the selection of the eggs for hatching purposes on the basis of size, and it is desirable to use no eggs weighing less than 2 oz. each. Moreover, it is

highly desirable to remove from the breeding flocks all birds that lay small eggs.

Shell Color Important.—In the case of varieties of chickens that lay white-shelled eggs, all eggs used for incubation should be free from tints. This is an economic factor that has caused considerable loss in marketing eggs produced by some strains of White Leghorns. Not only should tinted eggs laid by white-egg breeds be eliminated, but the birds laying the tinted eggs should be removed from the breeding flock.

Test for Cracked Shells and Tremulous Air Cells.—All eggs should be tested for cracked shells, and this can be done quite readily by tapping two eggs together. If there is a resonant sound, both eggs are sound in shell; but if there is a dull sound, one of the eggs is cracked and should not be used for incubation. Care should be exercised in shipping or delivering eggs to a hatchery to avoid excessive shaking that sometimes results in a condition known as "tremulous air cells," a condition that tends to lower hatchability, according to results secured at the National Agricultural Research Center.

Avoid Dirty Eggs.—Dirty eggs should not be washed before being set, because washing opens the pores and makes possible excessive evaporation of the watery content during incubation. If dirt is observed on the shell, scrape it off with a knife, or reject the egg.

Use Fresh Eggs Only.—Only fresh eggs should be set, because eggs for incubation deteriorate rather quickly after they are about 5 days old, while eggs 3 weeks old or more usually do not hatch at all. If the incubator capacity is relatively large, and a large number of eggs have to be saved before setting time, they should be kept in a cool room free from drafts and dust.

Position during Storage Not Important.—From the results of various investigations it is apparent that there are no advantages in keeping eggs in any particular position while being held for incubation, provided they are not kept over 5 days. They may be kept in a tray in their natural position and do not require to be turned.

Avoid High Storage Temperature.—The temperature at which eggs are held prior to being incubated is quite important, a high temperature being more injurious than a low temperature.

Just how low the temperature may be allowed to go without endangering embryonic development has not been determined, although rather low temperatures for short periods do not seem to be particularly detrimental.

As a general conclusion of the various investigations on the proper temperature at which to hold hatching eggs, it is apparent that about 55° is the best temperature. In warm weather, eggs should be gathered frequently and placed immediately in a temperature of about 55°. In sections of the country where subzero weather prevails in the early hatch-

ing season, the eggs should be gathered frequently to avoid the development of abnormal embryos and to secure the best results in hatching.

Proper attention having been given to the selection and holding of eggs for hatching, the next problem is to carry out the hatching work so that best results will be secured.

NATURAL INCUBATION

Raising chicks with hens is still practiced to a considerable extent. To be most successful it is necessary to have good brooding hens and properly constructed nests and to give the hens careful attention during the incubation period.

The Kind of Hen.—Hens selected for hatching purposes should have the broody instinct well developed, and each should be of such size as to cover properly the required number of eggs. A setting comprises from 11 to 15 eggs, the smaller number being set in the early part of the season, when the weather is cold, and 15 later, when the weather is warmer.

Breeds such as Plymouth Rocks, Rhode Island Reds, and Wyandottes are among the best sitters. The lighter breeds, such as Leghorns, generally cannot be relied upon.

The Kind of Nest.—The nest should be made of fine, soft hay, straw, or leaves and should be placed in such a position that the hen will not have to fly or jump into it. It should be large enough so that the hen will fill it nicely, affording complete protection for a single layer of eggs; if it is deep, the eggs may pile up and break.

Avoid Parasites.—Dust the hens thoroughly with sodium fluoride before setting them. Hens may become so badly infested with lice that they will leave their nests. To dust a hen, take her by the feet, holding her head downward, and rub pinches of sodium fluoride well into her feathers, especially around the vent. The proper method of treating a bird with sodium fluoride is shown in the chapter on Disease Prevention.

A careful lookout should be kept for the appearance of mites, which increase very rapidly in hot weather. If they appear, prompt eradication measures should be taken, as prescribed in the chapter on Disease Prevention.

Setting and Feeding.—Sitting hens should be kept in a room that is secluded, slightly darkened, cool, and apart from the houses for layers and breeders. A number of hens may be set at the same time, but each should be confined to her own nest. They may be fed together, but each hen should return to her own nest, and the door of the nest should be closed.

It is best to set hens after dark because they are less excitable then than in the daytime. Each hen may be tested for broodiness by placing two or three infertile or artificial eggs in the nest the first day. When she is sitting well, the hatching eggs may be placed under her.

Examine the nests occasionally to be sure that no eggs have been broken. In case any have been broken the shells and soiled nesting material should be removed and the rest of the eggs washed with warm water to remove any material that came from the broken eggs.

Feed the hens on hard grains, such as wheat, oats, corn, or a mixture of these, and occasionally some green feed. Keep grit and clean water before them always.

At hatching time allow the hens to sit quietly after the nineteenth day, but be sure that none leaves her nest with the first chicks hatched.

ARTIFICIAL INCUBATION

The domestic hen of today incubates its egg in precisely the same manner as the wild fowl of the bamboo jungles of India and Ceylon has incubated its eggs for many centuries. The modern incubator, however, incubates eggs in a very different manner from that employed by the Egyptians and Chinese in their mud ovens and barrels during at least the past several hundred years.

Ancient Methods of Incubation.—In contrast with the rather remarkable changes that have taken place during recent years in the development of the type of incubator for hatching chicks commercially in America, it seems strange that the methods of incubation used in the earliest times in Egypt and China are still in use there. The immense Egyptian hatching ovens, called *mamel el firakh,* constructed of sun-dried brick, mortar, and earth, usually have several compartments, each capable of holding a few thousand eggs.

The eggs are brought from many miles around the hatching oven on the backs of asses and camels. Heat is furnished by fires built in the rooms where the eggs are hatched, the proper temperature being maintained by the use of ventilators in the walls. The fuel is usually wheat or bean straw chopped and mixed with a certain amount of camel dung, or "gilch." No thermometer is used, since the attendant tests the temperature of the eggs by the touch of the hand or by placing them against the eyelid. The eggs are placed in the lower chambers and are often piled up four or five deep but not later than the tenth day are spread out in a single layer.

The eggs are turned three times daily. On the fourth or fifth day they are tested for fertility, the infertile eggs being removed and sold for human consumption. The testing is usually done in the upper chambers, each egg being held in a ray of sunlight which comes through a hole in the roof made for the purpose. No artificial moisture is provided, and no special provisions are made for securing fresh air.

The incubation methods of the Chinese are just as primitive as those of the Egyptians, but their incubators are different. There are three

types of Chinese incubators: mud-plastered, straw-covered, and muslin-covered barrels. Their general use is governed by locality; in the country

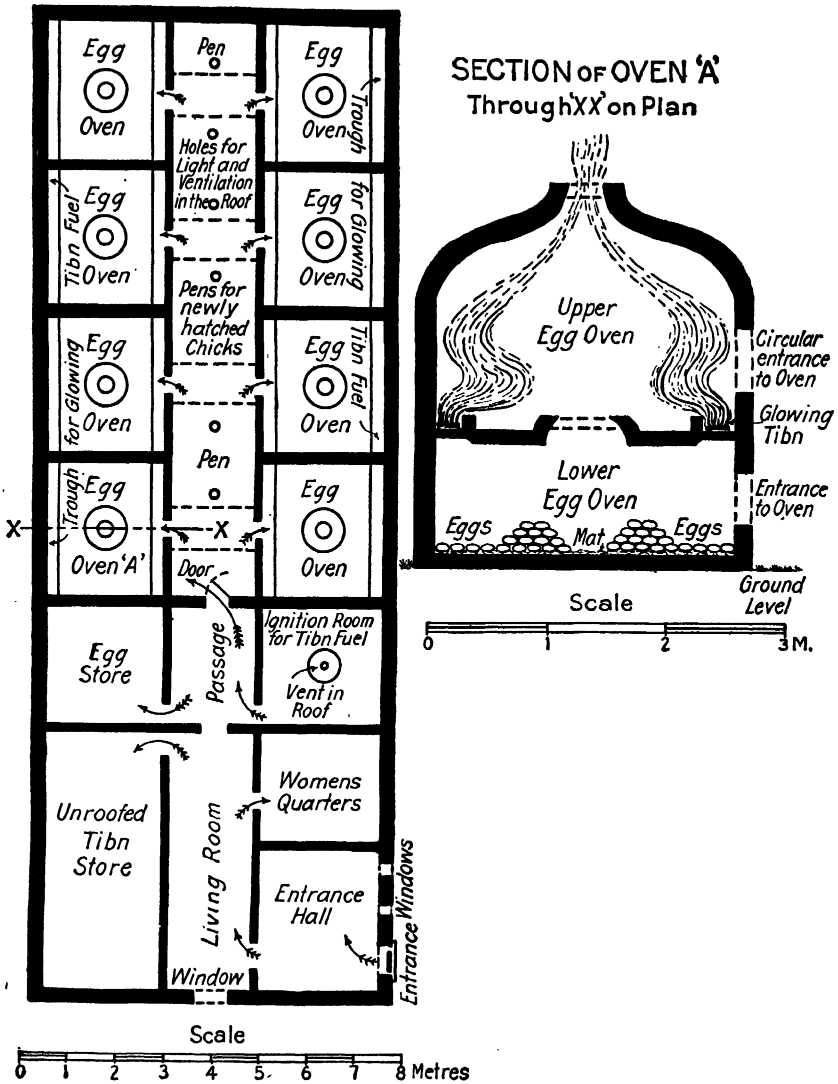


FIG. 56.—Egyptian hatching ovens are usually built of mud walls with circular openings to allow people to enter and to provide sufficient ventilation. The attendant frequently lives in one of the rooms of the oven and is extremely sensitive to changes in temperature. There is a dome-shaped roof with holes for smoke to escape.

Many of the ovens are composed of compartments, each compartment being divided into an upper and lower chamber. The eggs are placed on the floor of the lower chamber and are turned frequently. The fires are built around the walls of the upper chamber. (*Plan by Illustrated Poultry Record.*)

and village districts, where straw and mud are easily accessible, the first two types are preferred, while in the towns and cities the muslin-covered incubator prevails. Notwithstanding the differences in construction, the

method of heating each of the three incubators is practically the same, the heat being supplied by burning charcoal or by placing the incubators in piles of decomposing manure. As with the Egyptians, so with the Chi-

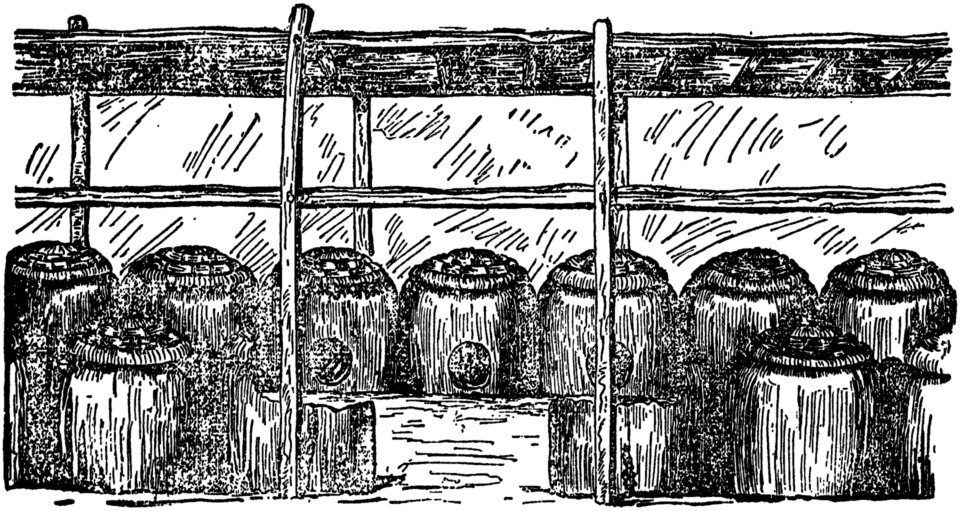


Fig. 57.—Showing the arrangement of Chinese incubators (*From Brill, U. S. Dept. Agr.*)

nese, the thermometer used in the modern incubator is almost totally unknown. A slight variation in the temperature is detected by placing a few eggs against the eyelid.

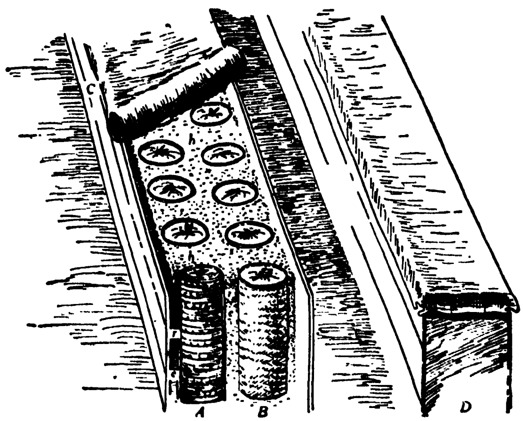


Fig. 58.—A diagrammatic sketch of a hatchery in Pateros the Philippines. *A*, *B*, and *D*, are rows of incubators (cylindrical baskets) in which *A* shows the basket in section to give an idea of the arrangement of the bags containing the egg to be incubated and those containing heated rice, *B* shows the entire basket, and *D* shows the row of baskets covered. This is also shown in *C*, but only partly rolled. *e*. Bags containing eggs. *r*. Bags of heated rice. *h*. Rice hulls firmly tamped and serving as insulators. (*Fronda*, 1925–1926.)

Modern Incubators.—The earliest of modern incubators appeared in England in 1770 and in America in 1844. The chief difficulty encountered in the operation of these early incubators was with respect to main-

taining a satisfactory temperature for successful incubation. It was not long, however, before mechanical devices for controlling the temperature were perfected to such an extent that the temperature throughout the 21 days of incubation could be controlled within a degree Fahrenheit variation from day to day. This was possible in spite of the fact that the developing embryos give off considerable heat during the latter part of the hatch. As far as temperature control in modern incubators is concerned, therefore, it has become a problem of determining optimum temperatures for the entire period of incubation.

Kinds of Incubators.—There are several different makes of incubators which differ in design, size, kind of fuel used, method of heating the eggs, method of ventilating the egg chamber, and method of providing humidity,

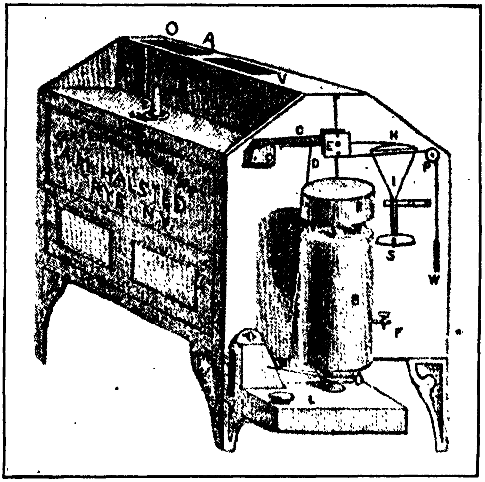


FIG. 59.—One of the earliest incubators in practical use in the United States. (*Photograph by Everybody's Poultry Magazine.*)

so that it is practically impossible to classify them in any systematic manner.

As far as design is concerned, incubators vary from the very simple boxlike or circular incubator of small size and sometimes cheap design to the mammoth roomlike incubator of substantial design equipped with a relatively elaborate well-constructed mechanism for providing optimum conditions of incubation.

The size of incubators differs from one holding approximately 50 to one holding several thousand eggs.

The fuel used may be coal oil, petroleum, gas, coal, or electricity, which is in reality a medium for the transference of heat rather than a fuel. In small incubators coal oil is frequently used to supply heat to the egg chamber. For incubators of larger egg capacity, gas, coal, or electricity is usually employed, the tendency being in favor of electricity. In sec-

tions of the country where natural gas is available, its use is usually justified from the standpoint of economy and ease of operation. Where neither gas nor electricity is available, coal may be used quite satisfactorily for supplying heat to large incubators in which hot water is used as a medium of heat transfer. The use of electricity in incubation is increasing in popularity because less labor is involved in incubator management, and when no heat is required no electric current is used, whereas when oil, gas, or coal are used any surplus heat produced above incubation requirements is usually diverted from the egg chamber.

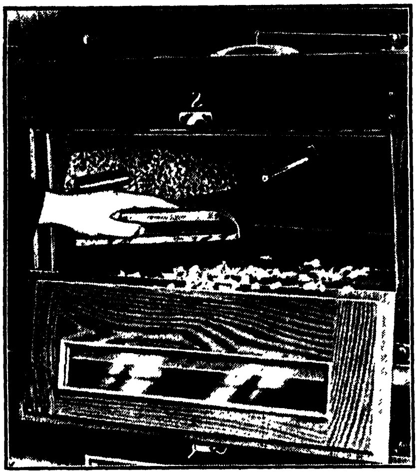


FIG. 60.—The thorough cleaning and disinfection of the incubator after each hatch is completed is a fundamental principle of successful incubation operation. (*Photograph by Buckeye Incubator Co.*)

Hot water and hot air are the mediums employed in transferring heat from its source to the egg chamber, except in the case of electrically heated incubators, which have their electric resistance coils located in the egg chamber. The hot-water and hot-air methods of supplying heat are equally satisfactory except that the former is less responsive to outside changes than the latter. Within the egg chamber the eggs are heated by the radiation of heat from water pipes, by an air drum or electric coils, or by the conveyance of warm air directly to the eggs; or by diffusion; or in rare cases by contact.

The method of ventilating the egg chamber differs among the different makes of incubators, particularly with respect to those which are or are not provided with a mechanically forced circulation of air through the egg chamber.

The method of supplying humidity to the atmosphere of the egg chamber varies from water pans under the egg trays to a special automatic humidifying device.

Incubators differ with respect to the size of compartment for holding the eggs; there may be a large number of small compartments in what is frequently called the "section-type" incubator, or there may be one large compartment for holding all of the eggs in what is known as the "cabinet-type," or "room-type," incubator.

The efficiency of operation of any particular make, design, or type of incubator depends largely upon the kind of materials used in its construction, how well it has been constructed, and its adaptability in providing the optimum conditions of incubation.

During recent years there has been a tendency on the part of the makers of large-capacity incubators to manufacture a separate hatcher to which eggs are transferred on about the eighteenth day of incubation. The use of the separate hatcher avoids any disturbance to eggs in the various stages of incubation prior to the eighteenth day. Moreover, there is no circulation or accumulation of down in the incubator used for incubating eggs up to the eighteenth day.

The Incubator Room.—In order that the incubator may give the most satisfactory results in hatching chicks, it should be located in a separate room not used for other purposes in order that (1) the incubator and incubator room may be kept as clean and free from disease organisms as possible; (2) an even temperature may be maintained in the room, thus making it easier to regulate the temperature in the incubator; (3) good ventilation may be secured to provide the incubator with fresh air and to remove the excess carbon dioxide given off from the incubator; (4) to make it a simple matter to provide the air of the incubator chamber with the proper relative humidity.

The size of the incubator room will depend, of course, upon the number and size of incubators that are required. The location of the incubators in the incubator room will depend upon the kind and size of incubator being used. Section-type incubators require that sufficient space be left between the incubator and the walls to permit of easy handling of the egg and chick trays and water trays, if they are used. Cabinet-type incubators are usually placed along the walls of the incubator room, with enough space left in the rear to make any necessary adjustments and to provide for proper cleaning.

A cellar room in the house may be used for small incubators that are heated by lamps, but for incubators of several thousand egg capacity a semibasement with the floor 3 or 4 ft. below ground level is almost ideal. In all cases, especially where the incubator room is entirely aboveground, it is well to prevent the sunlight from reaching the incubators. Manufacturers of various makes of incubators furnish plans of satisfactory incubator rooms.

Assembling the Incubator.—Assemble the incubator according to the manufacturer's directions, and see that it is perfectly level by using a spirit level or a shallow pan of water set on top of the incubator. The regulator should work freely. If the incubator door sticks, do not plane it off until the machine has been thoroughly dried.

There is sometimes considerable variation in temperature in different parts of the same incubator chamber so that thermometers should be placed in different places in the egg chamber, and temperatures compared.

Test the Thermometers.—Test all thermometers once a year with a clinical thermometer, which may be procured from a physician or at a

drugstore. Place the thermometers, including the clinical thermometer, in warm water, heated to about 103°F., taking care to keep the bulbs near each other and at the same level in the water. Incubator thermometers, if correct, register the same temperature as the clinical thermometer.

Starting the Incubator.—The printed regulations supplied by manufacturers should be followed closely until experience enables the operator to determine any minor variations that may be desirable. As pointed out previously, the forced-draft type of mammoth incubator requires a lower temperature than small incubators or mammoth incubators of the section type.

The following suggestions may be useful for those operating section-type incubators: Run the incubator at about 102° for at least 2 days

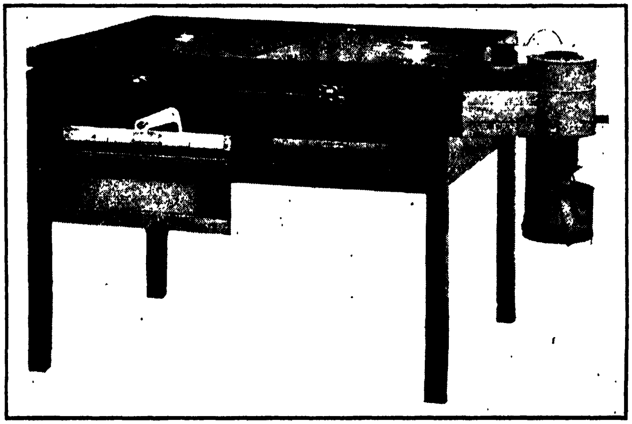


Fig. 61.—A typical lamp incubator, heated with kerosene. (*Photograph by Queen Incubator Co.*)

before putting the eggs in. Since it takes several hours for the incubator to come back to its correct temperature after the eggs are put in, the regulator should not be touched during that time. During the 21 days of incubation the temperature of the egg chamber may be regulated by lowering the flame of the lamp, or the regulator may be adjusted. The incubator should receive sufficient attention to avoid marked fluctuations in temperature. New section-type incubators should be started about one week before they are to be used in order that the temperature of 100° may be maintained and in order to make sure that the ventilating and humidifying apparatuses are functioning properly. The manufacturer's directions should be followed closely.

Care of the Heater.—In the case of lamp machines always use good oil. Clean and fill the lamp once daily, preferably in the morning, trimming the wick by scraping the charred portion off with a knife or by cutting the wick with scissors. The burners should be kept free from

dirt, and after each hatch they should be thoroughly cleaned by boiling. A new wick for each hatch is a good investment, thus eliminating any danger of the wick's becoming too short. Turn the eggs before caring for the lamp, so that there will be no chance of getting oil on the eggs. After the lamp is lighted the flame is apt to increase in size, so that it is well to wait a few minutes after lighting the lamp to see that the flame is the proper height.

In the case of incubators heated with coal or gas, the heaters should be thoroughly cleaned at frequent intervals. The flues and pipes should be kept in such condition that the heat supply at all times will be regular.

In the case of electric incubators the heating elements should be inspected and tested before the incubation season begins. The electric wires or coils should never be allowed to get wet, and the make-and-break switch should be kept free from oil, dirt, and dust.

Maintaining Proper Temperature.—The proper temperatures to be maintained in the case of the section- and cabinet-type incubators have been given previously, but in order to avoid the necessity of turning back the pages the information is repeated here.

In section-type incubators, without mechanically forced circulation of air, the temperature on a level with the top of the eggs on the egg tray should be maintained at 101.5° for the first 2 weeks and then 102.5° for the balance of the incubation period.

In cabinet-type incubators, with mechanically forced-draft circulation of air, a temperature of 100° should be maintained throughout the 21-day period of incubation, although some cabinet-type incubators may give better results when operated at 99°. It should also be kept in mind that, generally speaking, the operating temperature should be decreased as the relative humidity of the egg chamber increases and that when the relative humidity is low the temperature must be increased somewhat.

Effects of Current Interruption.—Although practically all modern makes of electric incubators are so well constructed that trouble is rarely experienced with respect to current interruption, occasionally a heating element may get out of order. Then, again, the thermostat may stick and cause overheating. The greatest danger with respect to current interruption is usually due to storms or floods which affect the central station or the home lighting plant. These interruptions are usually of short duration, largely because of the existing interconnection of power lines. Where such do not exist, it may be advisable for the hatchery operator to install an auxiliary current-producing plant.

The results of tests conducted by the California Experiment Station demonstrated, however, that 12 hr. of current interruption under room temperatures approximating 70° produced an average decrease in hatching results of 3.4 per cent. It would appear, therefore, that except under

extraordinary circumstances of prolonged current interruption no serious results should follow.

Alarm Systems.—All electric incubators should be equipped with an alarm system to warn the operator of an underheat or overheat supply. An alarm system that operates immediately when electric current interruption occurs is vitally necessary in order that the attendant may close the ventilators of the incubator to conserve heat. A reliable alarm

FIG. 62.—A mammoth-type incubator operated entirely by electricity. (*Photograph by Buckeye Incubator Co.*)

system to warn of an overheat supply is also necessary to provide against excessive embryo or hatching-chick mortality.

Providing Proper Ventilation.—The incubators should be ventilated so that the air in the incubator chamber contains 21 per cent of oxygen, the oxygen content of normal air, and the accumulation of carbon dioxide should not exceed about 0.5 per cent. The fact should not be overlooked that the ventilation of the incubator has a direct bearing on the relative humidity of the atmosphere of the egg chamber. The directions supplied by the manufacturers of the incubators should be based upon these principles.

Providing Adequate Humidity.—As pointed out previously, humidity is necessary in order to prevent the incubating eggs from losing too much moisture by evaporation of the water content of the egg through the porous shell and to provide for optimum conditions for the growth of the embryo. A relative humidity of 60 per cent should be maintained in order to secure the best hatches.

If a relative humidity of 60 per cent throughout the period of incubation is maintained, the eggs will not lose more than the proper amount of water. The simplest means of gaging the amount of moisture to be supplied as incubation proceeds is the size of the air cell in the egg. In most parts of the country there is little danger of supplying too much moisture, especially in the case of section-type incubators. As far as cabinet-type incubators are concerned, the directions of the manufacturers should be followed closely, since most manufacturers are aware of the optimum incubation conditions that should prevail in order to secure the best hatches.

The Position, Turning, and Testing of Eggs during Incubation.—It has been pointed out in the preceding section that the incubation of eggs may be carried on successfully if eggs are incubated in the horizontal position or at an angle of 30 or 45 deg., an angle of 30 deg. being preferable, the reason for placing eggs in the latter position being to conserve space. When eggs are incubated in a flat or perpendicular position they hatch well provided they are turned sufficiently often enough.

Beginning with the third day of incubation, the eggs should be turned five or six times daily, if practicable, and at least three times daily. The first turning should be as early as possible in the morning, and the last turning as late as possible at night. In small-capacity incubators, where the eggs are turned by hand, a few eggs should be removed from the front of the tray, and the balance gently turned by the palm of the hand. Shifting the eggs around on the egg tray and turning the tray end for end at each turning time tend to equalize the effects of any temperature differences existing in different parts of the egg chamber. Cabinet-type incubators are usually provided with mechanical turning or tilting devices. While the eggs are being turned, the incubator doors should be kept closed. The turning of eggs should be discontinued after the eighteenth day of incubation.

The eggs should be tested twice during the period of incubation, from the fifth to the seventh days, to remove all infertile eggs and those with dead embryos; and from the fourteenth to the eighteenth day to remove embryos dying after the first test. Many operators of mammoth incubators make one test about the fourteenth day, removing all infertile eggs and dead embryos at that time. Some operators do no testing during the entire period of incubation.

The testing should be done in a dark room or with a special device that can be used in the daytime. The eggs are tested with the large end up, so that the size of the air cell as well as the condition of the embryo may be observed readily. The infertile egg when held before the testing or candling device looks clear. A fertile egg tested at about the seventh day of incubation shows a small, dark spot, known as the "embryo," with a mass of little blood vessels extending in all directions if the embryo is living. If the embryo is dead, the blood settles away from the embryo toward the edges of the yolk, forming in some cases an irregular circle of blood known as a "blood ring."

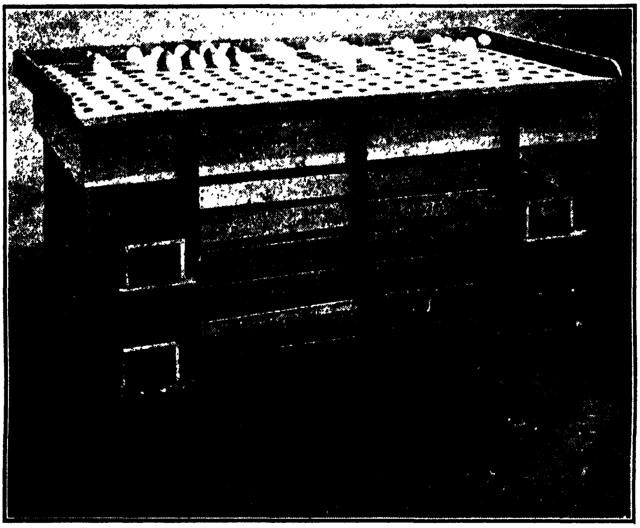


FIG. 63.—A table with drawers for holding hatching eggs from each breeding pen and indentations in the top of the table for sorting eggs by hen number. (*Photograph by U. S. Dept. Agr.*)

At the second test, on the fourteenth day, the eggs containing strong, living embryos are dark and well filled and show a distinct line of demarcation between the air cell and the growing embryo, whereas eggs with dead germs show only partial development and lack of this clear, distinct outline.

According to observations made at the National Agricultural Research Center, fertile and infertile eggs can be identified with a high degree of accuracy after about 15 hr. of incubation. For this purpose a 75-watt blue-green bulb should be used, or the person doing the candling should wear blue eyeglasses. The fertile egg can be detected by the presence on the surface of the yolk of a small spot about the size of a dime. The spot represents the embryo which causes the yolk surface to bulge slightly. Infertile eggs show no signs of embryo development.

Taking Off the Hatch.—The incubator doors should not be opened after the eighteenth day until the hatch is practically completed, for the

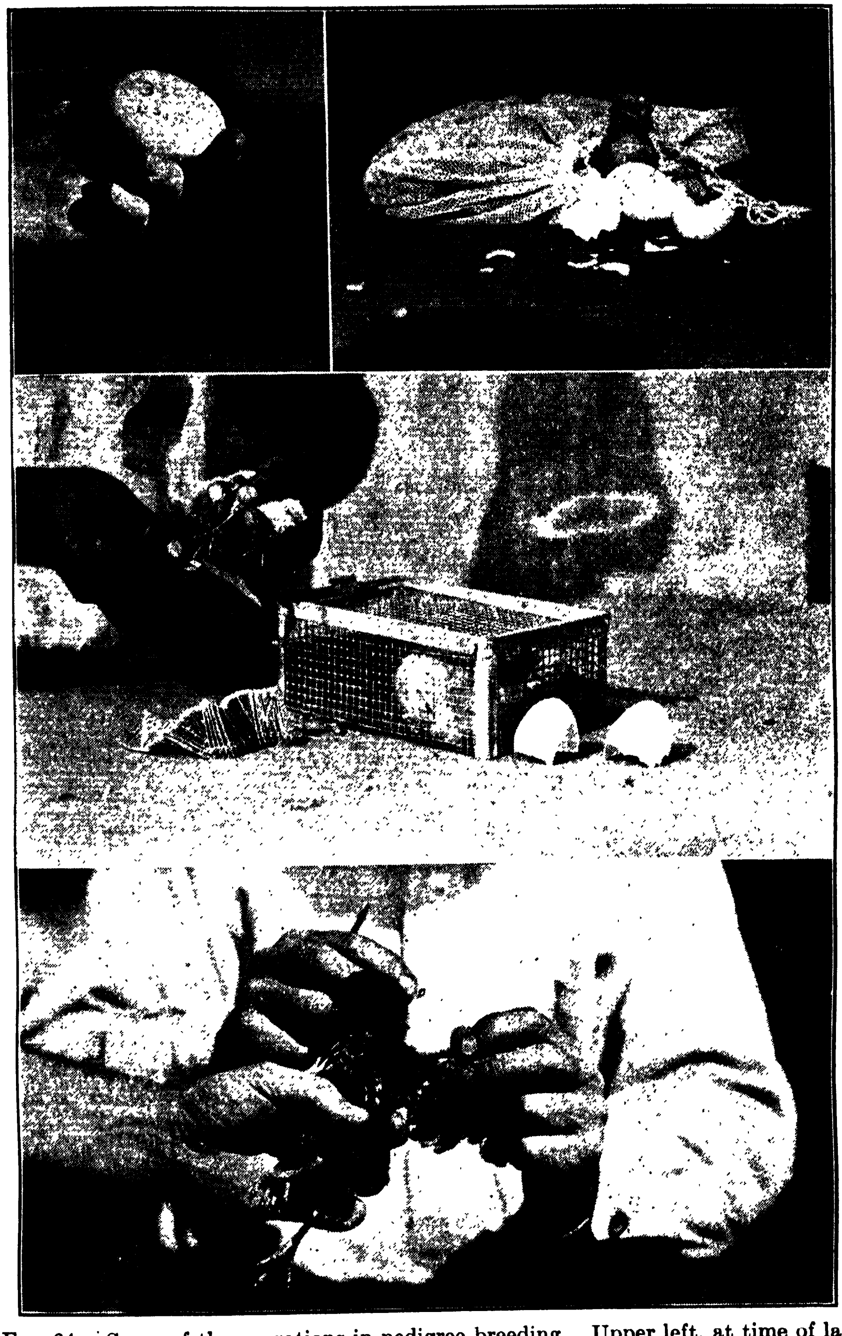


FIG. 64.—Some of the operations in pedigree breeding. Upper left, at time of laying, the egg is marked with the breeding pen number above and the hen number below. Upper right, a pedigree hatching sack containing the eggs from one hen only. Center, leg banding a chick taken from a pedigree basket. Bottom, wing banding a chick at 3 weeks of age. Chicks may be wing-banded at hatching time. (*U. S. Dept. Agr.*)

simple reason that opening the doors lowers the temperature and decreases humidity.

Most of the small-capacity or section-type incubators are provided with a movable wire piece in the front of the egg tray which is opened when the hatch is completed so that the chicks as they come to the front of the incubator fall down into what is called the nursery tray. The water pans should be removed before opening the wire piece at the front of the egg trays, but this should not be done until the chicks are dried off and well fluffed out. While the chicks are kept in the nursery tray the temperature on a level with their backs should be about 95°F., the door of the incubator being kept slightly ajar. During this time it is well to keep the incubator door darkened so that the chicks will not tend to pile up at the front of the incubator and will not pick at the droppings or at one another's toes.

In the case of cabinet-type incubators, the first chicks to hatch are often removed before the hatch is completed, especially if the hatching trays are crowded as the result of a very successful hatch. Empty shells are removed at the same time, but care must be taken not to chill the chicks still hatching.

Disposal of Infertile Eggs and Unhatched Chicks.—Incubation wastage in the form of infertile eggs and unhatched chicks is not usually a serious problem with the farmer or small operator, for in that case the refuse should either be burned or boiled thoroughly and used as hog feed. In the case of the large hatchery operator, however, the problem of disposing of incubation wastage is sometimes a serious one. Fertile eggs showing embryo development should not be sold for human consumption, the regulations of the Food and Drug Administration of the United States Department of Agriculture holding that such eggs are unfit for human consumption. They might be used for chick feed if thoroughly boiled to destroy any pullorum organisms that may be present. Infertile eggs and unhatched chicks might be disposed of as hog feed where there is a demand for them for this purpose. Perhaps the best way to dispose of infertile eggs is to break them at the hatchery plant, mix them with a disinfectant, and destroy them promptly so that they will not attract flies and will cause no bad odors at the hatchery plant. The same thing should be done with all unhatched chicks, using galvanized cans that do not leak.

Disinfecting Incubators.—After an incubator has been used once it should be thoroughly cleaned and disinfected, especially to prevent the spread of pullorum disease. Aside from the possible spread of pullorum disease, however, it is perfectly obvious that filth tends to accumulate in incubators that are used time after time and that the greatest possible precautions should be taken to clean and disinfect them thoroughly after

each hatch, because most diseases are filth borne. The egg trays and the inside of the incubator should be cleaned out thoroughly after each hatch and thoroughly disinfected with a 3 per cent solution of any of the standard coal-tar stock dips. The proper precautions to take to prevent the spread of pullorum disease in incubators is discussed fully in the chapter on Disease Prevention.

Insurance Restrictions When Using Incubators.—Farmers and others using incubators should keep in mind that there are certain restrictions on fire insurance of dwellings and other buildings in which incubators are used. Some insurance policies have no restrictions, whereas others have definite specifications to which the use of incubators must conform, and still others prohibit the use of incubators in any manner. In some cases special permission is required to operate an incubator. In any case it is well to look into the matter of insurance restrictions with respect to the use of incubators in dwellings and other buildings.

HATCHERY-MANAGEMENT PROBLEMS

In 1918 it became possible to ship baby chicks by parcel post, and since that year the growth of the breeder and commercial hatchery industry has been nothing short of phenomenal. There are now over 12,000 breeder and commercial hatcheries in the United States with a hatching capacity of well over 300,000,000 eggs at one setting. This is sufficient egg capacity to produce over 750,000,000 chicks if the hatcheries are operated on the average of two and one-half settings per season, which is customary in normal times.

Successful Hatchery Operation.—In order to operate a hatchery most successfully certain principles of fundamental importance must be kept in mind. The various items that determine the results from the operation of a hatchery would include:

1. The knowledge the hatchery operator possesses concerning poultry and the poultry industry. The greater the poultry knowledge the hatchery operator possesses the more likely is he to command respect and confidence among farmers and poultrymen who buy chicks.

2. A pleasing personality is an important factor in enabling the hatchery operator to command the respect of the flock owners supplying eggs to his hatchery.

3. Good business ability is most essential in successful hatchery operation not only from the standpoint of keeping accurate records of expenses and receipts in the operation of the hatchery but also from the standpoint of selling his chicks to best advantage. To ignore the vital necessity of keeping complete records in the operation of a hatchery is to invite failure. In order to manage a hatchery most efficiently the hatchery operator must practice sound business methods.

4. The location of the hatchery is an important factor in determining success, for the simple reason that most of the chicks are sold locally. Therefore, the hatchery should be located where there is likely to be a good demand for chicks within a radius of approximately 50 miles from the hatchery.

5. The hatchery plant should be attractive in appearance, both outside and inside, should be kept clean and sanitary, and should be so arranged as to promote the greatest efficiency in its operation. Prospective purchasers of chicks often pass judgment on the chicks produced

FIG. 65.—Producing chicks by the thousands at a commercial hatchery. Here is shown a series of mammoth incubators of the forced-draft type of air circulation. (*Photograph by Smith Incubator Co.*)

by the appearance of the hatchery plant. The layout of the hatchery plant should provide for the convenience of flock owners delivering their eggs and for chick customers.

The office should be in a separate room, and if possible the machines in which the chicks are hatched should be kept in a separate room from that containing the incubators in which the eggs are incubated up to the eighteenth day. A large hatchery plant should provide an egg-receiving and -traying room where the eggs are received from the flock owners, sorted, and trayed. This room should be kept cool at all times so that the eggs are maintained in a temperature of about 55°, and the air should have a relative humidity of about 60 per cent. The general supply room in which egg cases and chick boxes are kept should also be separate from the incubating and hatching rooms. There should be a chick-sorting and -shipping room.

Cement floors with drains are most desirable for the incubator rooms because they can be kept clean and sanitary and also because they can be watered for the purpose of maintaining the proper degree of relative humidity. The incubators should be placed on bases so that the bottom of the incubator is 2 or 3 in. above the floor.

The proper ventilation of the incubating and hatching rooms is imperative in order to provide the embryos and chicks with a sufficient supply of oxygen and to remove the carbon dioxide liberated by the embryos and chicks. The cooperation of the incubator manufacturer should be sought with respect to providing adequate ventilation for the incubators installed.

The temperature of the incubating and hatching rooms should be kept as near 70° as possible.

The Egg Supply.—Since the majority of hatchery operators do not possess flocks of sufficient size to produce all the eggs for the hatchery, it is necessary for them to purchase eggs from a number of flock owners. Therefore, it is obvious that if the hatchery operator is to secure the best results in hatching he must take a vital interest in the quality of eggs produced by the flocks from which he secures hatching eggs.

One of the most important things for the hatchery operator to keep in mind at all times is that the quality of hatching eggs cannot be improved after they are produced. The hatchability of the eggs determines the number of chicks to be secured, assuming that conditions of incubation and the management of the hatchery are ideal. Good chicks cannot be hatched from poor eggs. Furthermore, poor-quality chicks usually require more replacements and give rise to more dissatisfied customers; repeat orders decrease, and the hatcheryman's reputation is impaired. Therefore, the hatchery operator is under distinct obligation to all flock owners supplying eggs to his hatchery to cooperate with them in a sound breeding and improvement program designed to supply the hatchery with the highest possible quality of hatching eggs. This is in the best interests of the hatchery operator as well as in the best interests of the flock owner.

One of the very best incentives to encourage flock owners to produce eggs of the highest possible hatchability is for the hatchery operator to pay a premium for the hatching eggs he receives from each flock owner on the basis of the hatching results secured from week to week, the premium on the basis of hatchability being in addition to the ordinary premium over the price of market eggs.

For the average hatchery, approximately 1,000 to 1,200 breeding females are needed for each 10,000 egg capacity. The number of flocks required depends, of course, upon their size, but it should be obvious to any hatchery operator that a flock owner having 300 or 400 birds can be more readily induced to undertake a sound breeding and flock manage-

ment program for the production of high-quality hatching eggs than a flock owner having only 50 or 100 birds.

Hatchery operators should enter into agreements with flock owners supplying eggs to their hatcheries whereby the flock owner agrees to furnish hatching eggs of a certain minimum size, keep and feed his flocks according to the directions supplied by the hatchery operator, and have the flock officially tested for pullorum disease. The most successful hatchery operators are those who secure the most complete cooperation of their flock owners based on the mutual benefits accruing to all.

The Length of the Hatching Season.—Except in those localities where there is an extensive commercial broiler industry, most hatcheries sell the great majority of their chicks between the first of March and the last of May, the peak of the output being during April. The hatching of chicks during January and February is sometimes justified in spite of the relatively high hatching-egg costs and relatively lower hatchability than from March to May incubation. Sometimes January- and February-hatched pullets are liable to undergo an early fall molt. Moreover, extremely early hatching is very liable to lead to a surplus of chicks, resulting in price cutting, which is very bad for the hatchery industry. Then, again, June- and July-hatched chicks are very liable to give poor results in the hands of the buyers, because chick mortality is apt to be higher and rate of growth less satisfactory than in March-to-May-hatched chicks. On the other hand, there is some justification in selling fall-hatched chicks to poultrymen who want their pullets to start laying in the summer months.

Avoiding a Surplus.—One of the cardinal principles in the successful operation of a hatchery is to avoid the accumulation of surplus chicks beyond the number ordered for sale. Hatchery operators should avoid surpluses by setting eggs according to the number of chicks ordered. The most successful operators, who have established a reputation for the quality of chicks they sell, usually have no difficulty in disposing of the same or an increasing number of chicks year after year. It is to the hatchery operator's own advantage to set only a sufficient number of eggs to fulfill the chick orders on hand, except for a reasonable allowance for late orders.

Sexing Chicks.—The business of segregating males and females among day-old chicks by examining the rudimentary copulatory organs has become well established in some sections of the country. The sexing of chicks at hatcheries is carried on most extensively in the commercial Leghorn sections of the Pacific Coast states, where there is usually a limited market for Leghorn cockerels as broilers.

Success in sexing chicks depends upon one's ability to distinguish the rudimentary copulatory organ or process, which is nearly always present

in a well-developed condition in males but is nearly always absent in females. A considerable amount of training and experience are necessary to enable one to sex chicks with a high degree of accuracy at a fast enough rate to make the undertaking an economic success at most hatcheries.

Since several different kinds of processes are encountered and the technique of sexing is rather complicated, lack of space prevents a detailed discussion of the various processes and means of identifying them. The proper training in sexing chicks can best be obtained from a thoroughly experienced operator.

Judging Chicks for Quality.—It has been observed previously that the quality of the chicks at hatching time is determined largely by the

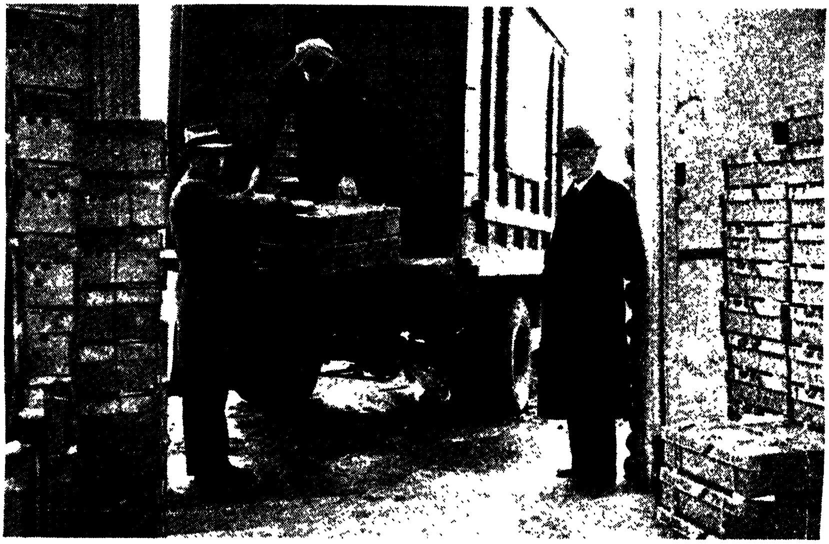


FIG. 66.—Loading chicks at a hatchery for shipment by truck. (*Hatchery Tribune.*)

quality of the eggs from which the chicks were hatched and by the conditions of incubation. Baby-chick shows have become quite a prominent feature in many sections of the country and are a splendid means of stimulating interest in the production of high quality chicks. The score card for judging chicks, shown in Fig. 67, is largely self-explanatory and serves to emphasize the more important characteristics that distinguish chicks of superior quality from defective and otherwise inferior chicks.

Selling and Shipping Chicks.—Selling the chicks produced at a hatchery plant to best advantage is of paramount importance in the successful operation of a hatchery. The chicks should be priced, of course, in relation to their quality. The selling of chicks below the cost of production is distinctly detrimental to the best interests of the hatchery business and the poultry industry and ought to be discontinued. Moreover, the shipping of chicks to chick auctions and shipping to fictitious addresses

QUALIFICATIONS AND POINTS (25-CHICK ENTRY)	No.	Cuts	Perfect Score	Entry Score
VIGOR			30	
Lacking in substance in handling.... (Cuts 1/4 to 1)				
Lacking alertness, and lacking full bright eyes (Cuts 1/8 to 1/2)				
Shanks small and dried up.......... (Cuts 1/8 to 1/2)				
CONDITION			30	
Chicks showing defects:—Side sprigs, stubs, comb, off type; crooked legs, toes, neck, or back (Cut 4)				
Imperfectly-healed navels.......... (Cuts 1/8 to 1/2)				
Pasty vents...................... (Cuts 1/4 to 1)				
Sticky hatch and short or thin down.. (Cuts 1/2 to 1)				
UNIFORMITY OF COLOR			20	
Down color varying from standard or average (Cuts 1/8 to 1/4)				
Shank color varying from standard or average (Cuts 1/8 to 1/2)				
UNIFORMITY OF SIZE			10	
No. varying more than 2 grams from average (Cut 1/4)				
WEIGHT—(Standard—2 lb. 1 oz. for 25 chicks)				
Ounces under weight........ (Cut 1 point per oz.)			10	
Dead chicks........................ (Cut 4 points)				
TOTALS			100	

EXPLANATION OF CUTS IN JUDGING CHICKS

A cut of four (4) points will be made for each chick showing any of the following:

1. Type of comb not characteristic of the breed.
2. Side sprig on comb of single-combed breeds and varieties.
3. Feathers on shanks or down between toes of clean-shanked varieties.
4. Deformed chicks.

CONDITIONS ELIMINATING CHICKS FROM COMPETITION

An entry will be eliminated from competition if generally inferior and lacking breed characteristics, if showing evidence of disease; or evidence of having been fed.

FIG. 67.—Score card for judging chicks, with the cuts to be imposed for chicks lacking in various quality characteristics.

are practices that should be prohibited for the simple reason that they interfere unfairly with the legitimate operations of honorable hatchery operators.

In the advertising and selling of chicks the fair-trade practice rules for the baby-chick industry of the Federal Trade Commission should be followed implicitly.

The successful selling of baby chicks depends first upon the quality of chicks being offered for sale and second upon the ingenuity of the hatchery operator. The hatchery operator who has established a reputation for selling high-quality chicks that live and do well in the hands of

Fig. 68.—Baby chicks are often shipped by the carload. (*Hatchery Tribune.*)

the customer usually has no difficulty in maintaining an established business.

The newly hatched chicks should be culled carefully, preparing for shipment those with bright eyes, bright yellow beaks and shanks in yellow-skin breeds, and pinkish tinged beaks and shanks in white-skin breeds, well fluffed-out down, freedom from defects and deformities, and well healed at the vent. The shipping of high-quality chicks to customers is a good investment.

Chicks are usually shipped in boxes containing 100 chicks, the box being divided into four compartments each containing 25 chicks. The size and dimensions of baby-chick boxes recommended for shipping baby chicks are as follows:

25-chick box, 9 by 12 by 6 in. high, inside dimensions.
50-chick box, 12 by 15 by 6 in. high, inside dimensions.
100-chick box, 18 by 24 by 6 in. high, inside diemnsions.

The chick boxes should be properly ventilated according to the season of the year.

The number of boxes that can be tied together for parcel post or express shipment is governed by regulations of the U. S. Post Office Department, and these should be followed in order to secure the most satisfactory service in the shipping of chicks by parcel post. Whether chicks are shipped by parcel post or by express, they are expected to reach their destination within 72 hr. from the time of hatching. Special delivery trucks, sometimes equipped with a special ventilating device, are used by many hatchery operators in delivering their chicks to customers.

The Responsibility of the Hatchery Operator.—The evolution of the hatchery industry has demonstrated that the hatchery operator is coming to assume a more dominant role than ever in the future development of the industry simply because each succeeding year sees a relatively higher proportion of the country's chick population secured from the breeder and commercial hatcheryman. To a considerable extent the hatchery operator is responsible for improving conditions in the poultry industry because the quality of chicks produced by hatcherymen determines, in a large measure, the results that farmers and commercial poultrymen secure from the chicks they purchase. It is obvious, therefore, that the character of business done by the hatchery operator has a very direct bearing on the future development of the poultry industry.

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CHAPTER VI

REARING PRINCIPLES AND PRACTICE

The success achieved in rearing chickens is determined, first, by the quality of chicks that have been produced and, second, by the environmental conditions, including the kind of diet and method of feeding, to which the chicks are subjected. Ideal methods of rearing will not compensate for poor quality in the chicks at hatching time. On the other hand, chicks of superior quality can be severely damaged by improper conditions of rearing.

Brooding is a phase of rearing chicks, being the phase when the chicks need heat. Later comes the further rearing of the chickens under range or battery conditions. Whatever may be the method employed during the brooding season and later, it is of fundamental importance that the growing chicks be kept comfortable, fed adequate diets to promote good growth, and kept under such environmental conditions that they will produce the most economical results for whatever purpose they may be produced.

BUYING DAY-OLD CHICKS

Inasmuch as the success usually attained in brooding and the later rearing of chicks is dependent upon the quality of the chicks, it is most important that the purchaser of day-old chicks take every precaution possible to see that chicks of the best quality only are secured.

Because of the very rapid development of the commercial and breeder hatchery business in the United States, the practice of buying chicks hatched commercially increases from year to year. It is very important that those who buy day-old chicks from commercial hatching establishments pay particular attention to the kind of hatchery from which they purchase their chicks.

The quality of chick produced in a hatchery is determined to a large extent by the quality of eggs used in the hatchery and the methods employed in incubation. Day-old chicks of the highest quality are produced in those hatcheries where the breeders in the breeding flocks producing the eggs for the hatchery are selected carefully, only the best birds being used as breeders. The breeders should always be in the best of health, and should be tested for the pullorum disease, and the poultry plants should be kept in sanitary condition at all times. The eggs sent

to the hatcheries should be of good size, as well as uniform in shape, shell color, and shell texture. The hatcheries should be kept in strictly sanitary condition at all times, and the management of the incubator should be such as to produce chicks of the highest possible quality. Before placing an order for day-old chicks, buyers should make a careful inquiry concerning flock management and hatchery-operation methods employed by the hatchery operator.

The proper time to buy chicks depends, of course, upon the purpose for which the chicks are being bought. Most chicks bought by farmers and commercial poultrymen are obtained for the purpose of raising pullets as replacements in the laying flock. In order to have the pullets begin laying in September and October, Leghorn chicks should be purchased from about Mar. 15 to May 1, and chicks of the larger breeds should be purchased from about Mar. 1 to Apr. 15.

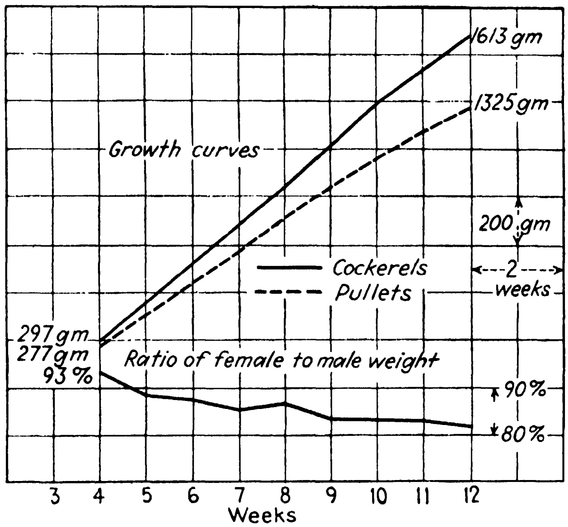


FIG. 69.—Growth curves of chickens, showing that cockerels grow faster than pullets. (*Holmes, Pigott, and Campbell*, 1932.)

SECURING GOOD GROWTH

The fundamental problem of importance in the rearing of chicks is to secure the optimum rate of growth and, at the same time, have a minimum amount of mortality. In order to attain these objectives certain factors pertaining to the growth of chicks should be kept in mind because they have an important bearing on management problems involved in brooding and rearing.

In the first place, it should be borne in mind that cockerels grow faster than pullets, as shown in Fig. 69, so that allowance should be made in providing brooder capacity when "sexed" chicks are bought. In the second place, it is well to remember that chicks of the heavier breeds, such

as Plymouth Rocks and Rhode Island Reds, increase in body weight at a faster rate, as shown in Fig. 70. It follows, therefore, that relatively

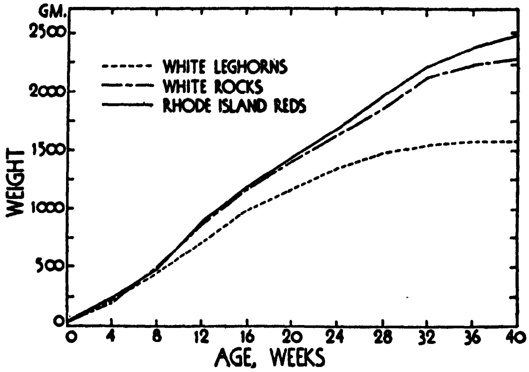
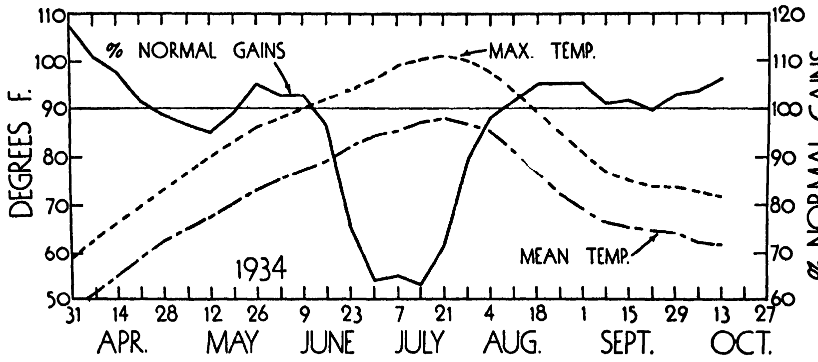


FIG. 70.—Normal growth curves for White Leghorn, White Plymouth Rock, and Rhode Island Red pullets, showing that the chicks of the heavier breeds increase in weight more rapidly than Leghorn chicks. (*Kempster and Parker*, 1936.)



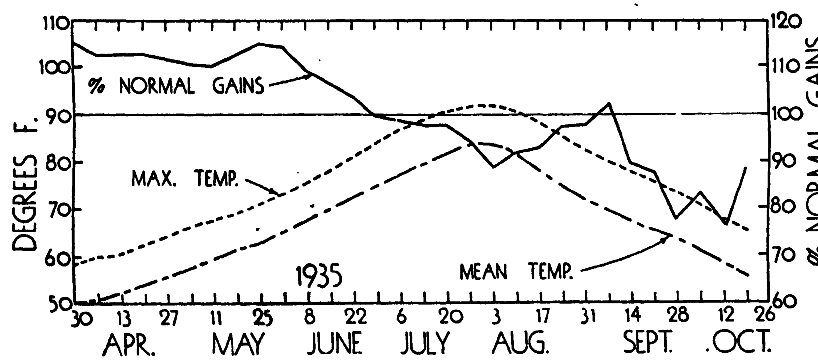


FIG. 71.—Showing the relation of average monthly temperature to the percentage of normal monthly gains in weight of pullets. Hot summer weather tends to retard growth. (*Kempster and Parker*, 1936.)

more space must be provided for chicks of the larger breeds than for those of the smaller breeds. In the third place, it has been shown that excessively hot weather tends to retard growth, so that ample shade and

well-ventilated brooding and rearing houses are of great importance if the optimum rate of growth is to be obtained.

The Missouri Agricultural Experiment Station has demonstrated that April- and May-hatched chicks do not grow so well during the first 20 weeks as February- and March-hatched chicks. The high temperatures that usually prevail in the southern sections of the United States during the summer months tend to retard growth, as shown in Fig. 71. At 28 to 32 weeks, however, the later hatched chicks had attained approximately the same body weight as the earlier hatched chicks.

For the purpose of securing egg production from pullets when the yearling and older hens are molting, during June, July, and August, some poultrymen purchase chicks in November and December. Fall or winter chicks require more careful management than chicks bought during the spring months.

Chicks for broiler production are sold the year round, many broilers now being brooded in batteries in confinement.

NATURAL BROODING

The brooding of chicks with hens is still practiced on many farms and by those raising only a few chicks in the backyards in towns and cities. Success in raising chicks with hens is dependent largely upon the careful attention given to details of management. It is best that the hen remain on the nest and brood the chickens for about a day after they are hatched. When giving chickens to a hen that already has some to brood it is best to add chicks of the same color and age as those already with her, because some hens often peck the late arrivals if they are of a color different from those already being brooded.

Depending upon her size, a hen will brood from 12 to 15 chickens successfully early in the season and from 15 to 20 in warm weather. Chicks hatched during the cold weather of winter should be brooded in a house or shed; but after the weather becomes more favorable they should be brooded out of doors, using brood coops to confine the hens. Brood coops should be made so that the chicks can run in and out at will but closed at night to keep out cats, rats, and other animals; there should be ventilation, however, enough to give the hen and chicks plenty of fresh air. The construction of brood coops should be such as to permit them to be cleaned easily and disinfected thoroughly.

The hen should be confined in the coop until the chicks are weaned, the chicks being allowed free range after they are a few days old. The coop should be large enough to give the hen plenty of freedom and keep her in good physical condition. It is well to move the coop to fresh ground at least once a week to prevent the soil from becoming contaminated and to give the hen fresh green feed regularly.

ARTIFICIAL BROODING ON RANGE

Artificial brooding is recommended for practically all poultry raisers, especially where considerable numbers of chicks are to be raised. The use of a brooder reduces the amount of labor required in brooding chicks and is more economical when a few hundred or more chicks are raised annually. Also, when the chicks are hatched in incubators or when day-old chicks are bought from a commercial hatchery, the brooding of chicks with brooders is a practical necessity.

Brooders may be classified as follows: lamp brooders holding from 25 to 100 chicks; electric brooders of various sizes, accommodating from 50 to 500 chicks; stove brooders heated by coal, kerosene, or distillate oil, with a capacity varying from 200 to 1,000 chicks; hot-water-pipe

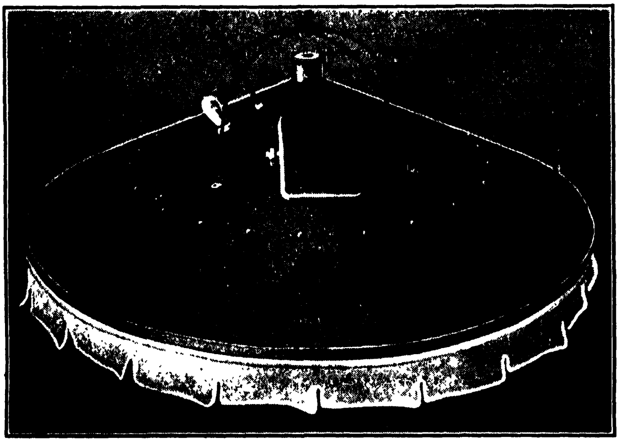


FIG. 72.—An electric brooder of the convection type. Heavily insulated hover with double-zone brooding space. (*Lyon Electric Co.*)

systems, the capacity of which is unlimited; and battery brooders especially designed for brooding chicks in confinement.

Lamp Brooders.—Lamp brooders usually use kerosene oil as the source of heat. The danger from fire caused by carelessness or lack of proper attention makes it practically necessary to use lamp brooders in small brooder houses located at some distance from larger buildings. In attending the lamp, care should be taken to keep the wick and burner properly cleaned. Brooder lamps should be inspected several times a day. Do not fill the lamp entirely full of oil, because the heat from the lamp will expand the oil in the bowl and may cause it to overflow and catch fire.

Electric Brooders.—Electric brooders are being used more extensively each succeeding year, especially in those sections where the cost of electric current is comparatively low. The current must be dependable at all times during the brooding season, because if it is off for a few hours the

chicks may become chilled, and high mortality result. In many sections of the country, especially where chicks are brooded early in the season, it is necessary sometimes, though not always, to heat the brooder room with an auxiliary heating system to 60 to 70° in order to maintain the proper temperature under the hover of an electric brooder. The most recent innovation in the manufacture of electric brooders has been the installation of a fan in the ventilating shaft of each brooder for the purpose of maintaining an even temperature and to remove excessive moisture which may otherwise accumulate under the hover.

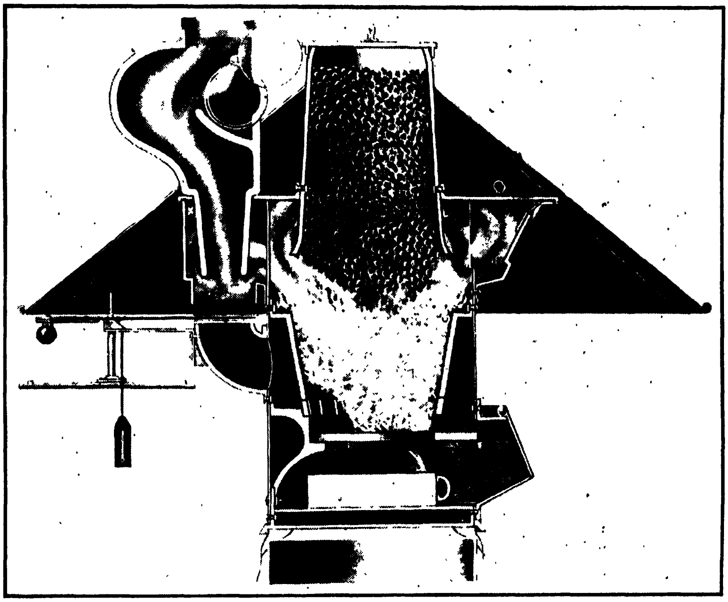


Fig. 73.—The coal-burning brooder stove is one of the most successful ways of brooding chicks in colony-brooding houses, where the chicks are given range. (*Buckeye Incubator Co.*)

Stove Brooders.—Brooders heated by coal are coming into very general use everywhere, especially where hard coal is readily available, while similar brooders heated with engine distillate oil are used extensively on the Pacific Coast. These brooder stoves have a capacity of about 250 to 1,000 chicks each, but the brooding of not more than 250 chicks in one flock usually gives better results than when larger numbers are brooded together.

Most of these stoves have hovers, although a few of the oil stoves do not, those with a hover being preferable. The use of hard coal of chestnut size is advised for the coal-burning brooder stoves, although in some sections where hard coal can not be obtained and soft coal is abundant, the latter may be used, but in that case the brooder requires more frequent attention. Most of the oil brooders are equipped with a wafer regulator which controls the flow of oil, which is fed automatically from

a tank or barrel outside the house. Several stoves may be connected with the same supply tank. Brooder stoves heated by kerosene are used somewhat in the East, but their use is not nearly so common as that of the coal-heated brooders, and they have not proved to be so satisfactory. In the colder parts of the country it is frequently difficult to get heat enough from kerosene-heated stoves when brooding chicks early in the season. More recently, stove brooders have been manufactured that are adaptable for burning wood.

Homemade Brooders.—In some sections of the country where hard coal is difficult to obtain and the rates for electric current are high, homemade brooders have been devised which burn wood or soft coal. Most of the homemade brooders use wood as the source of heat. They have proved to be particularly popular throughout the South.

Selecting a Brooder.—The selection of the brooder is a very important matter because the successful brooding of chicks is frequently a difficult problem. Cheap, unreliable brooders may easily ruin many broods of good chicks. A reliable make will more than repay the difference in cost between it and a poor one in the first brooding season through lessened mortality and better growth of the chicks. Above all, be sure that the brooder is made of good material and that the thermostat is well made. The latter is a particularly important feature, because a poorly made thermostat or one that gets out of order readily may allow the temperature to rise until the brood of chicks is ruined or to drop so low that the chicks become chilled.

Starting the Brooder.—Chickens are usually left in the incubator from 24 to 36 hr. after hatching, without feeding, before they are removed to the brooder, which should have been in operation 3 or 4 days at the proper temperature for receiving chickens. A beginner should try his brooding system carefully before he uses it. Early mortality in chicks is frequently a result of the chilling they receive while they are being taken from the incubator to the brooder and also the result of not having the brooder running properly when they are first put under the hover. In cool or cold weather the chicks should be moved in a covered basket or other receptacle.

The floor of the brooder house should be covered with about 1 in. of cut clover, alfalfa, straw, or shavings. In case neither cut clover nor alfalfa can be obtained, sand may be used, although if the chicks are not fed properly they are inclined to eat the sand, and that sometimes causes loss. The litter should be removed frequently, as cleanliness is essential in raising chicks.

At first when chicks are put into the brooder they should be confined under or around the hover by placing a board or wire frame or guard a few inches outside. The fence or guard should be moved farther and farther

from the hover and discarded entirely when the chicks are 3 or 4 days old or when they have learned to return to the source of heat. The chicks should be watched closely to see that they do not huddle or get chilled. If they begin the bad habit of toe picking, remove the wounded ones and

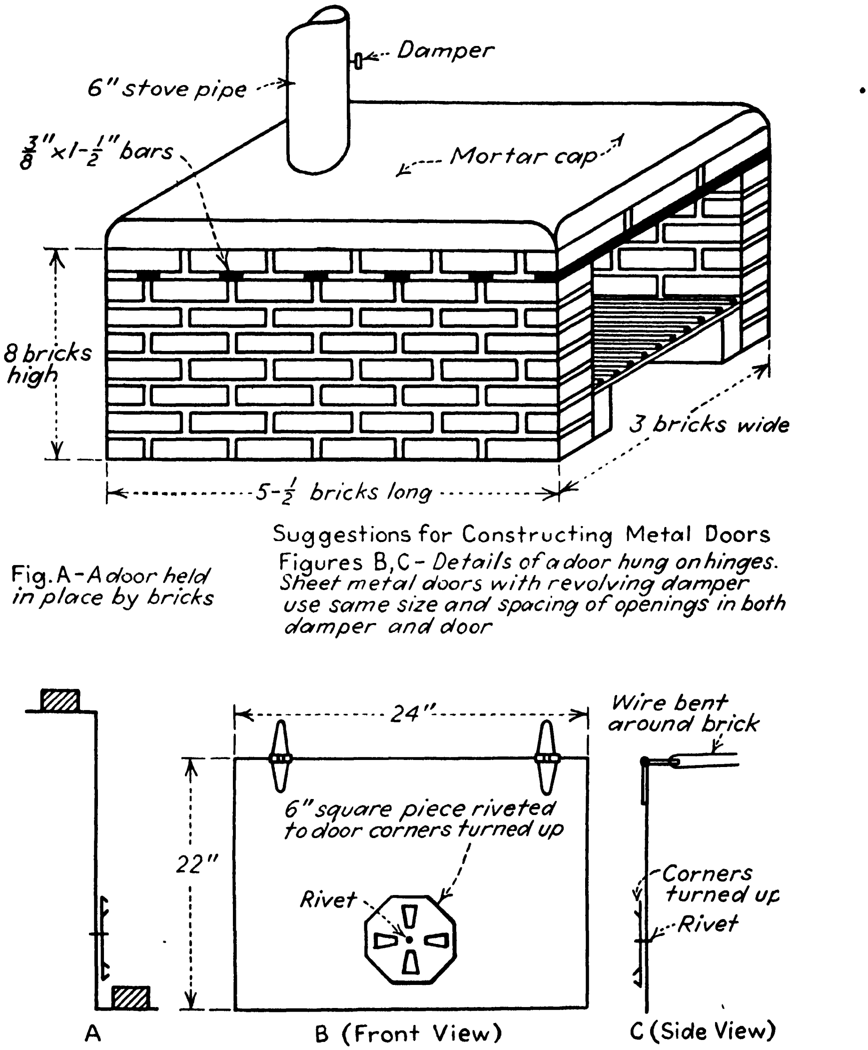


FIG. 74.—Brick brooder stove for burning wood or coal. The grate and one course of brick may be omitted if coal is not to be used. (*Humphrey and Kelley*, 1936.)

paint their toes with tar. Getting the chicks outdoors will serve to check the habit.

Regulating the Temperature.—The best temperature at which to keep a brooder depends on the position of the thermometer, the type of the hover, the age of the chicks, and the weather conditions. Aim to keep the chicks comfortable. When too cold they will crowd together and

try to get nearer the heat. If it is found in the morning that the droppings are well scattered under the hover it is an indication that the chicks have had heat enough. If the chicks are comfortable at night they spread out under the hover of the brooder, and the heads of some protrude from under it. Too much heat causes them to pant and gasp and sit with their mouths open. Excessive heat tends to weaken their vitality.

It is impracticable to state the temperature at which brooders of each type should be kept. In most cases the brooder should be run at about 100°F. at about 2 in. above the floor, when the chicks are first put in, and the stove brooders should be kept at that temperature for the first few days, because the chicks are able to adjust themselves to the heat, moving nearer or farther from the heat, according to the outside temperature.

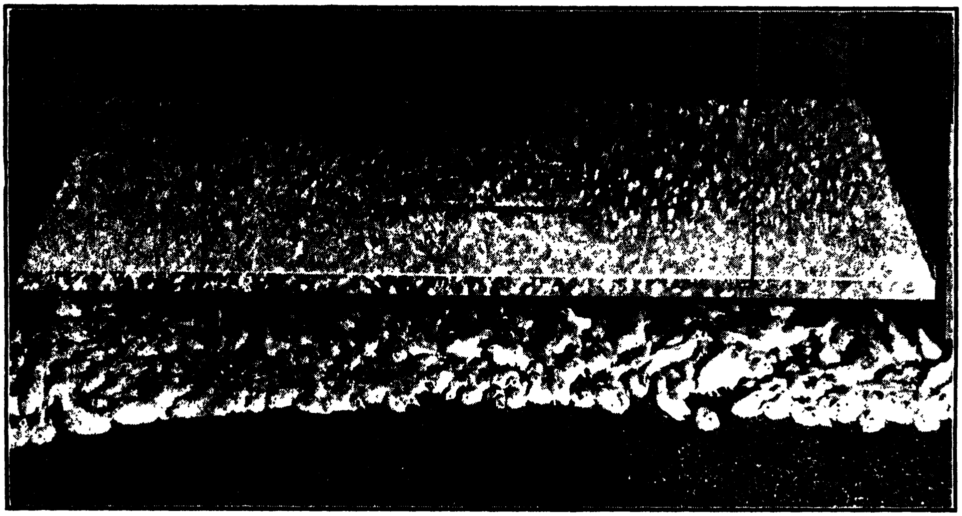


FIG. 75.—One section of a continuous hot-water-pipe brooding system. (*Shenandoah Mfg. Co.*)

The temperature is lowered, of course, as the spring season advances and as the chicks begin to feather out. Experienced operators usually regulate the temperature by the condition and behavior of the chicks from day to day.

Maintaining the proper temperature on windy nights is frequently a problem when coal-burning and wood-burning brooders are used. If the fire goes out during the night because of too much draft, the chicks are certain to become chilled and are likely to pile up in one corner of the brooder house. A well-constructed, automatic wind damper set in the stovepipe will greatly decrease the tendency of the fire to go out, because the wind damper opens with the increasing draft that is caused by a strong wind.

The use of electric brooders requires a dependable supply of electric current at all times during the brooding season. An alarm system should

be installed to warn of any interruption in the current supply. In using electric brooders the following points should be kept in mind from the standpoint of the safety of the operator. One should never attempt to work with a "hot," or "live," circuit. Open the circuit switch or remove the circuit fuses first; while 110 volts will seldom injure one, there are conditions under which it may do harm. All electric wires should be considered hot unless the circuits have been opened or are known to be open. A shock received from the ordinary electrical appliances generally indicates poor electrical insulation. One should never work with a power

FIG. 76.—The hot-water-pipe brooding system is used by many poultrymen, both for the production of broilers and for the raising of pullets for egg production. (*Shenandoah Mfg. Co.*)

circuit when standing on wet ground or wet floors or when in water or allow the body to become a part of a circuit; the body can form a circuit either to "ground" or to the opposite power "leg." It should always be remembered that both legs of an alternating-current circuit as usually operated are live. The circuits should be fused on both legs and for about 125 per cent of full load. These fuses will protect the electrical apparatus and the circuit.

Where the electric current is dependable at reasonable rates, the use of electric brooders is to be recommended chiefly because an even temperature can be maintained and the temperature can be lowered gradually according to the age of the chicks and the season of the year. A well-

insulated brooder-house floor is of vital importance in the successful operation and most efficient use of electric brooders.

While it is very important to provide proper temperature under the hover during the period of brooding, it is also important to provide proper temperature in the brooder house. The house temperature should be approximately 60°F. during the first 3 or 4 weeks of brooding.

Providing Ventilation.—The proper ventilation of the brooder is necessary, since water vapor and carbon dioxide given off by the chicks tend to accumulate beneath the hover of the brooder when curtains are used or when the ventilation is restricted.

FIG. 77.—Teaching the chicks to roost early is not only the best way of insuring their comfort but also reduces mortality. (*U. S. Dept. Agr.*)

Oil-heated portable hovers are usually so constructed that they radiate heat from a drum and heat the air under the hover, the cooler air being forced out. Coal-burning and wood-burning brooders also usually provide for good circulation of air, inasmuch as the hover acts as a deflector. Unless a hover has a positive system of fresh-air ventilation, however, it should not sit closer than about 4 in. above the floor, and if curtains are used they should hang about 2 in. above the floor and should be raised as the chicks increase in size.

Providing adequate ventilation under the hover is particularly important when electric brooders are used. From the standpoint of ventilation, there are two types of electric brooders, one ventilated by the gravity system, and the other by the electric-fan forced-air system. The gravity-ventilated brooder is provided with an adjustable flue which may be closed or opened to control the circulation of air. The fan-forced-air ventilated brooder is provided with a small electric fan at the top of the

hover, air being forced into the hover from above. From results secured at the California Agricultural Experiment Station, it was found that a flow of 2 cu. ft. of air per minute for every 100 chicks was necessary to keep the hover reasonably dry until the chicks were 3 weeks old. Since the adequate ventilation of electric brooders is so important, the directions supplied by the manufacturers should be followed.

Providing Plenty of Room.—It is a common practice on the part of many to brood too many chicks together. When it is realized that chicks usually double their original weight in less than 2 weeks, it is readily understood how quickly they may become overcrowded if too many are placed under the brooder at the start. The larger the number of chicks brooded together usually the slower the growth and the greater the mortality.

Most of the brooders on the market are overrated as to the optimum number of chicks they can accommodate. Leghorn chicks require from 7 to 10 sq. in. each, and chicks of the larger breeds require from 10 to 12 sq. in. each, of floor space under the hover. Since a hover 56 in. in diameter has a hover area of 2,463 sq. in., this size of brooder would accommodate 250 Leghorn chicks and 225 chicks of the larger breeds. The brooding capacity of brooders of other sizes should be determined on the same basis. Moreover, brooding chicks in lots not to exceed 250 promotes better growth, and there is usually less mortality than when chicks are brooded in larger numbers.

The brooder house should provide plenty of room, a minimum of 50 sq. ft. floor space per 100 chicks being found necessary for best results.

TABLE 30.—PER CENT CHICK MORTALITY IN RELATION TO FLOOR SPACE PER 100 CHICKS
(Buster and Newlon, 1924)

Floor space per 100 chicks, square feet	Number of chicks	Mortality	Per cent mortality
Less than 35	73,007	19,254	26.3
35.0 to 49.9	25,371	4,122	16.2
50.0 and over	25,044	3,484	13.1

A 56-in. hover with 250 Leghorn chicks would require a brooder house having at least 125 sq. ft. floor space, and the same hover with 200 chicks of the larger breeds should be in a house of about the same size for the simple reason that at 6 and 8 weeks of age these chicks are larger than Leghorn chicks.

When the chickens are fairly well feathered, low roosts should be placed in the rear of the brooder house. The chicks will soon learn to roost, and this will prevent overcrowding on the floor. Moreover, by

encouraging early roosting, the chicks are more likely to secure an abundant supply of fresh air each night. It is advisable to place wire netting under the roosts to keep the chicks from scratching in the manure.

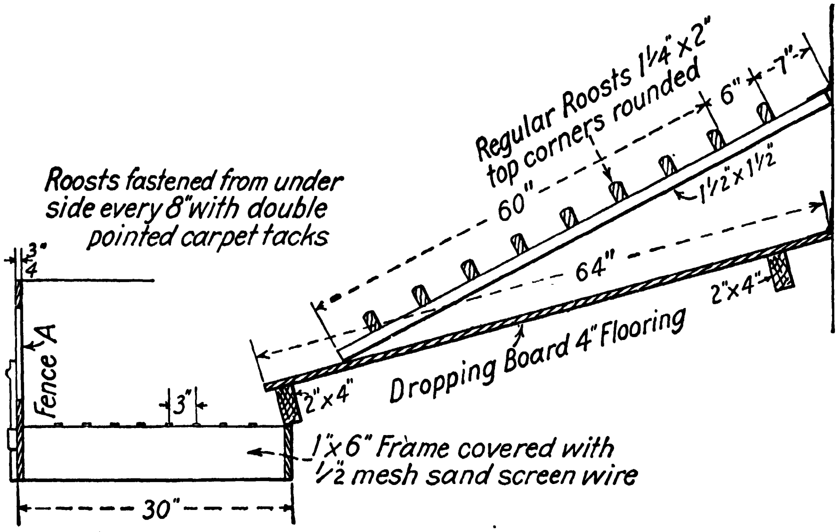


FIG. 78.—A device for teaching chicks to roost while quite young. (*Shoup*, 1927.)

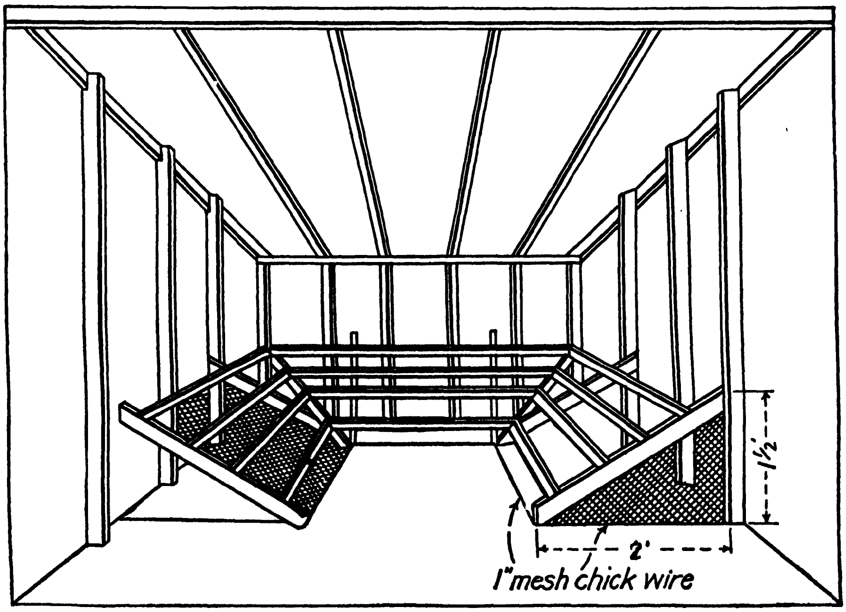


FIG. 79.—Chick roosts arranged in the brooder house to encourage early roosting. Wire netting prevents the chicks from crowding into the corners and keeps the chicks away from the droppings. (*Ill. Agr. Exp. Sta.*)

Separate the Sexes Early.—The sexes should be separated at about 8 weeks of age in order to give the growing pullets as much room as possible to develop into good layers. The pullets should then be placed on land

over which other birds have not ranged that season. The cockerels may be sold at separating time as broilers or kept to be sold later as fryers or roasters.

Maintain Dry Litter.—A dry floor and dry litter in the brooder house are very necessary in order to keep the chicks in good health and to promote the best rate of growth. Particular care must be exercised in keeping the litter dry when electric brooders are used. Dampness is conducive to the spread of disease, especially such as coccidiosis.

On the other hand, a word of caution is necessary against having the atmosphere of the brooder house too dry. This sometimes occurs when homemade brooders are used, in which case a pan or pail of water placed on top of the brooder will overcome the difficulty.

Disinfect Frequently.—Disease organisms of various kinds are sooner or later bound to gain access to the brooding quarters so that regular and thorough disinfection of the brooders and brooding equipment is a vital necessity. The interior arrangements of the brooding quarters should be such that all exposed surfaces may be properly cleaned and thoroughly disinfected. For information on disinfection see the chapter on Disease Prevention.

REARING ON RANGE

The amount of range to be provided for the growing stock is a very important matter. Too often insufficient range is provided, with the result that the land soon becomes bare and polluted with droppings containing worm eggs and disease organisms. For each 100 chicks there should be range available amounting to approximately 100 by 100 ft., and this range should be kept with a fresh green crop. After the chickens have been removed from the houses, the land in the immediate vicinity should be limed heavily, ploughed, and sown to a green crop to be ready for chicks again in 2 years if this range is required in that time. It is advisable to rear young stock on land that has not been used the previous year.

Not only does a good grass range for growing chickens provide succulent green feed and prevent soil erosion, but the nutritive value of the grass grown on such range is enriched. Some very interesting observations have been made on the improvement of Downland pastures in England after poultry had been kept on them for some time. There was a marked increase in the crude protein, silica-free ash, and phosphoric acid contents of both spring and autumn herbage.

Range Shelters.—In many sections of the country range shelters are used extensively for protection for the growing stock during the summer months, a common form of range shelter being shown in Fig. 80. They are usually of sufficient size to be portable and are built of wire netting

on the four sides. They are used on many farms and commercial poultry plants where the chicks have been brooded in confinement or semiconfinement for about 8 weeks, and then the range shelters are used.

Proper Growing Conditions.—After the sexes are separated, the pullets should be gone over rigidly from time to time in order to remove any unthrifty ones. The growth of the pullets to maturity should proceed without interruption, because checking the growth at any stage may retard laying.

The house in which the pullets are kept should be provided with plenty of ventilation without being drafty. Comfort during the nights is of paramount importance, and if the pullets are kept in the houses in

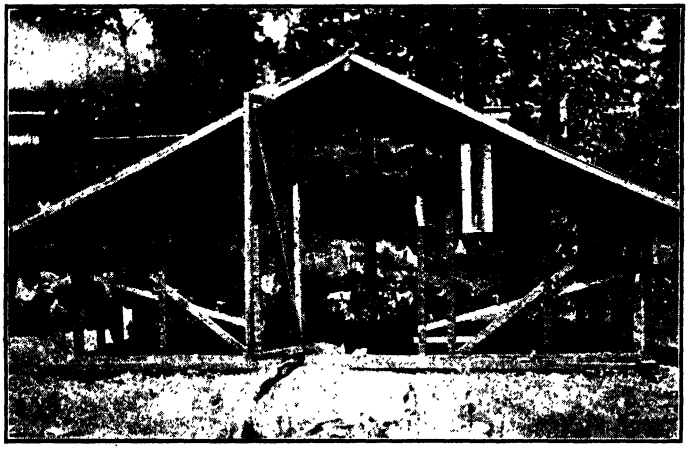


FIG. 80.—Range shelter for growing chicks during the summer months. It provides shade during the daytime and abundance of ventilation at night. The structure is 12 ft. wide by 10 ft. deep. (*N. J. Agr. Ext. Service.*)

which they were brooded, then adequate ventilation by having windows on at least two sides of the house is necessary.

Good range on a grass sod is very effective in providing proper growing conditions. A good grass sod provides sanitation and an abundance of succulent green feed, and thus the pullets are kept in the best possible state of health.

Rearing conditions for the cockerels, especially when they are kept as breeders, should be such as to promote the best possible growth. The cockerels should be provided with good range shelters or good housing conditions and good range. The cockerels ought to be reared as free as possible from parasites and disease, and this can be done best on clean grass sod or other clean range.

Importance of Sanitation.—Inasmuch as it has been demonstrated many times over that the results secured in brooding and subsequent methods employed in rearing chickens to market age or for laying purposes depend to a large extent upon the quality of the chicks and the

environmental conditions under which they are kept, the importance of sanitary control measures is given special emphasis at this time. Lack of proper sanitation is one of the most frequent causes of failure in brooding chicks.

The importance of sanitation in raising chicks is becoming more thoroughly appreciated by all poultry raisers. This has resulted very largely from the success achieved in the "Grow Healthy Chicks" campaign originally inaugurated in Connecticut. The following outline gives the essential features of chick-raising plans now in use in many states, the

FIG. 81.—The chicks are given range but for the first few days are confined to a limited range in front of the brooder house. (*U. S. Dept. Agr.*)

results secured indicating that mortality during the growing period has been very greatly reduced:

1. Clean chicks.
   a. Start with chicks secured from breeding stock that has been officially tested and found to be free of pullorum disease.
   b. Start with chicks secured from breeding stock in which there has been little mortality from other diseases, especially fowl paralysis.
   c. Start with chicks secured from strains of breeding stock that have demonstrated their ability to produce vigorous chicks having low mortality.
   d. Start with chicks hatched in clean incubators.
2. Clean brooder houses.
   a. Clean, scrape, and scrub, using hot water and high-test lye.
   b. Disinfect thoroughly.

c. Whitewash the entire interior.
d. Clean all equipment used for brooding.

3. Clean litter.
    a. If straw or similar nonabsorbent litter material is used, change litter every week if it becomes damp or wet.
    b. If peat moss or other absorbent litter material is used, litter need not be changed as long as it is kept dry. Stir daily to promote drying, and add more as needed. Remove litter immediately if it becomes wet.

FIG. 82.—Good range and plenty of shade are important factors in the successful rearing of pullets to maturity. (*U. S. Dept. Agr.*)

4. Clean feed and water.
    a. Place all feed troughs and water vessels on wire platforms in the house.
    b. Use dry wells beneath automatic water fountains in order to keep the litter dry.
    c. Move hoppers and movable water pans to a clean spot on range each week.
5. Clean range.
    a. Land not used by poultry for 2 years or more.
    b. Land removed from previous range as far as possible.
    c. Land not contaminated by drainage water or poultry manure.
    d. Clean brooder houses before moving to clean range.
6. Clean management.
    a. Keep young stock entirely separated from old stock.
    b. Avoid overcrowding.

c. Encourage early roosting.
d. Teach chicks to range by moving feed and water from the house.
e. Provide some natural shade.
f. Move to clean ground when disease threatens after thoroughly cleaning and disinfecting the houses.
g. Discourage visitors from entering the brooder houses and walking over the range.

The following table gives the results secured in reducing mortality in Connecticut for the years 1926 and 1927, there being 502,938 and 552,882 chicks, respectively, under observation. Mortality is based on the number of chicks raised to maturity.

TABLE 31.—PER CENT MORTALITY UNDER THE CONNECTICUT GROW HEALTHY CHICKS PLAN
(Jones, 1928)

Year	Mortality occurring when the following points were adopted			
	All 6 points, per cent	All 6 points except clean chicks, per cent	All 6 points except clean land, per cent	All 6 points except clean chicks and clean land, per cent
1926	7.9	15.3	....	22.0
1927	6.9	14.4	13.9	17.9

The data given in the preceding table show that two of the most important factors in reducing chick mortality are (1) chicks that have been secured from a breeding flock from which the pullorum disease has been eliminated and (2) the raising of the chicks on land that is not contaminated with parasites and disease organisms.

ARTIFICIAL BROODING IN CONFINEMENT

In some sections of the country, especially where commercial poultry raising is carried on extensively, chicks are brooded in confinement for the first few weeks. A number of years ago this practice was followed where broilers were being produced commercially but was abandoned as a general practice because of trouble experienced in leg weakness in the chicks and because of the heavy mortality frequently encountered.

More recently, however, the practice has been resumed as a result, largely, of the discovery that proper proportions of vitamin D in the diet prevent leg weakness. Another reason for the resumption of the practice was that when chicks were reared on the same ground year after year, various troubles were frequently encountered, such as coccidiosis, intes-

tinal roundworms, and tapeworms. Poultrymen found that soil that had been allowed to become contaminated with disease germs and infested with worm eggs was an unsafe place on which to attempt to raise chickens. Brooding chicks in confinement was adopted as an alternative to providing new range or cleaning up the old range.

One advantage in brooding chicks on the floor in confinement is the saving of labor, particularly in the case of large numbers of chicks. A hot-water-pipe brooder is frequently used in a long brooder house, which is divided into a number of pens, each large enough to accommodate from about 250 to about 1,000 chicks. Such an arrangement requires much less labor in tending the chicks than is the case when the chicks are brooded in colony houses 100 ft. or more apart. This saving of labor is an important matter, but brooding chicks in large lots increases mortality and retards the growth of the chicks.

The battery brooder system is being used extensively in the brooding of chicks in confinement. Battery brooders consist of single or double rows of tiers of wire cages one above the other. There are two kinds of battery brooders on the market: those equipped with an electric heater in each compartment and those that depend entirely upon the temperature of the room in which the brooders are kept for supplying the necessary heat for the chicks.

The use of battery brooders reduces the amount of labor required to brood a given number of chicks as compared with range-brooding methods. There is also the possibility of giving the chicks more careful supervision; and chicks of different ages do not get mixed, as is frequently the case on range. Under the battery system of brooding it is possible to obtain complete records of feed consumption and body weights of the chicks, thus making it possible to control disease more readily than when chicks are reared on range, although heavy mortality in batteries has frequently occurred from different diseases, particularly coccidiosis.

One of the disadvantages in battery brooding is the prevalence of toe-picking, feather picking, and cannibalism. In case any of these troubles occur, it is recommended that all light be excluded except that from a 60- or 100-watt natural-colored ruby Mazda bulb, glass not inside frosted, and reflectors used to throw the light on the feed and water troughs. Some operators spray the windows with a rich red lacquer paint which may be easily removed after the brooding season is over.

Proper Temperature Important.—It is very necessary to maintain the proper temperature in batteries, 96° being desirable for the first 3 days, after which it should be lowered about 3° every 3 days for about 3 weeks. After the third week the temperature of the battery room should be maintained at about 72°. The night temperature should be about 5° higher than the day temperature.

Ventilation and Humidity Requirements.—Where large numbers of chicks are kept in batteries in a room, special provision must be made for supplying adequate ventilation and proper humidity. If the room is not too large, the intakes and outlets employed in a typical ventilation system will probably suffice, but for a large room full of batteries an air-conditioning unit is usually necessary. For large installations a qualified engineer should be consulted.

Humidity is necessary to keep the chicks in the best state of health, promote optimum growth, and keep the feathers from becoming too dry. For about the first 3 weeks a relative humidity of about 60 per

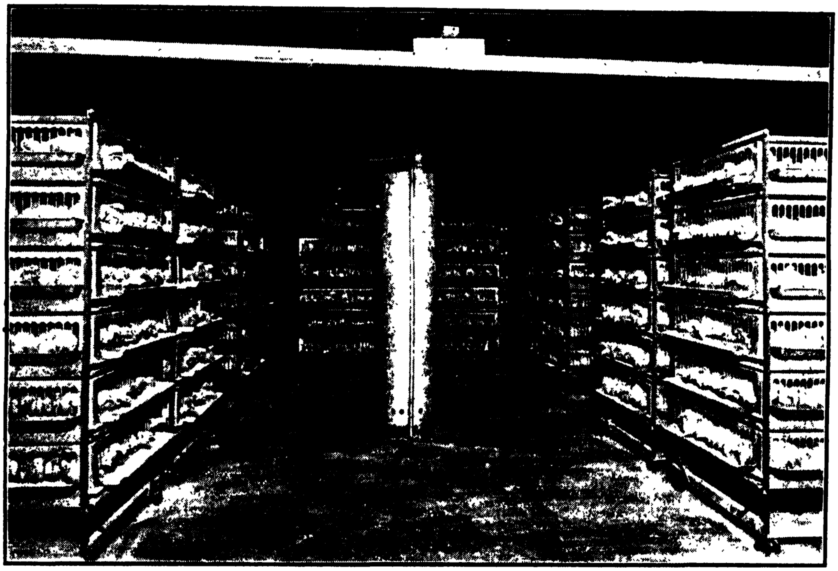


FIG. 83.—The use of battery brooders is a very satisfactory way of brooding chicks for the first few weeks. (*Kerr Chickeries.*)

cent should be maintained, after which it may be reduced to about 45 per cent.

Avoid Overcrowded Batteries.—Or , of the most important things to be kept in mind in battery brooding is to avoid overcrowding the chicks in the batteries. Under good conditions of brooding, chicks grow fast and soon overcrowd the batteries. Just as soon as the chicks do not require heat, if they are being brooded in batteries with electrically heated brooders, they should be transferred to larger sized unheated batteries. Not only is better growth attained, but better feather development and better shank color are obtained when the chicks are not overcrowded during any stage of battery brooding, as shown by the results secured at the Larro Research Farm. Mortality is also reduced when the chicks are not overcrowded.

The minimum floor-space requirements in battery brooders that have been recommended by some operators are as follows:

Age of Chicks, Weeks	Square Inches per Chick
1 to 2	10
3 to 4	20
5 to 6	30
7 to 8	40
9 to 10	55
11 to 12	75

With a few slight changes, the following observations are based on the results secured at the Larro Research Farm. The cubic inches of battery space rather than the square inches of floor space are the proper criteria upon which to determine the space requirements of the growing chicks. For most rapid gains, at least 1 cu. in. of space is necessary for every gram of live weight, or at least 450 cu. in. of space for every pound of live weight, regardless of the number of chicks. It was found that restricting space below the optimum exerted an unfavorable influence not only upon growth but also upon livability, pigmentation, and feathering. The incidence of respiratory diseases increased as the cubic space decreased.

It was found that in batteries that were crowded, the temperature in the battery compartment increased above the room temperature. The batteries that were most heavily crowded with chicks were at times 23°F. higher than the room temperature, while the sparsely populated compartments showed little or no difference in temperature over that maintained in the room.

Battery-brooder Management.—In order to insure success in battery brooding, the results must be such as to justify the costs of installation and maintenance. Operating costs must be kept as low as possible, and at the same time the management must be such as to keep the chicks in the best possible state of health combined with good growth and feather development. For the commercial production of broilers it is very essential to secure rapid growth and well-finished carcasses which are free of breast blisters.

Many operators prefer battery brooders with the contact type of heat unit, which permits the chicks to get away from the source of heat for feed and water and return to the brooding section when they feel the need of warmth. The temperature of the room should be approximately 60°F.

A building about 20 ft. long by 15 ft. wide is large enough for a broiler plant selling approximately 150 broilers weekly. The ceiling should be high enough to allow adequate ventilation, 10 ft. being desirable. The batteries should be at least 15 in. apart, and the aisles between the rows

of batteries should be at least 3 ft. wide. A building 20 by 15 is large enough for three starting and four finishing batteries, the chicks being transferred to the finishing batteries at about the end of the fourth week. The building should be well insulated, the method used being such as to keep out mice and rats.

The battery-brooding room should be illuminated uniformily, the lights being so arranged that the feed and water troughs are well lighted, but very little light should reach the interior of the batteries. If the building has the proper amount and arrangement of window space, it is possible to do away with artificial illumination except on dark days.

Since too high a room temperature tends to promote cannibalism and poor feather development, many operators who have a large battery-brooding plant install an automatically controlled oil-burning hot-air heating system. Evenness of temperature is relatively easily maintained, and, in addition, it is possible to humidify the air of the battery room.

The feed and water troughs should be adjustable and should be raised as the chicks increase in size; otherwise breast blisters are apt to develop. The troughs should be kept scrupulously clean at all times, and every precaution taken to prevent the feed and water from becoming contaminated with disease organisms.

The batteries and all equipment should be cleaned and disinfected thoroughly after each lot of chickens is removed. Disease organisms lurk in corners and cracks, and it is only by thorough scrubbing with stiff brushes that most of the filth can be removed from the various parts of a battery. It is largely a waste of time and money to disinfect an improperly cleaned battery. The floor of the building should be provided with a drain, and the floor itself should be scrubbed and disinfected thoroughly at regular intervals.

Although the brooding of chicks in batteries has its advantages, it must be pointed out that the methods of management, including the diet fed, are much more exacting than when chicks are brooded on range. For the production of broilers on a commercial scale, brooding in confinement has proved satisfactory, but where pullets are being raised for laying purposes it is undoubtedly advisable to give them range on clean soil, at least after the first 2 or 3 weeks of confinement, or semiconfinement, brooding.

REARING IN CONFINEMENT OR SEMICONFINEMENT

When chicks are brooded in confinement and are still kept in confinement either in battery brooders or in pens with wire-screen floors, they must be given careful attention. The brooding of chicks in battery brooders and in pens equipped with wire-screen floors is a sanitary precau-

tion against infection from intestinal parasites and disease, such as coccidiosis.

Avoid Overcrowding.—One of the chief dangers in the rearing of chickens in confinement is the tendency to overcrowd them in the space allotted to them. The sexes should be separated at about 8 weeks of age, as in the case of the rearing of chicks on range. The cockerels may be sold as broilers, or some of them may be kept as breeders. At any rate, it is necessary to keep both pullets and cockerels under the best of environmental conditions. As the chickens grow they should be separated to other batteries so as to avoid overcrowding. Avoiding overcrowding is of paramount importance in preventing excessive losses.

FIG. 84.—Confinement rearing with a sun porch, using ¾-in. wire mesh, for the bottom, with 1-in. mesh siding. The feed hoppers are placed on the outside of the sun porch. (*Wm. C. Monahan.*)

Plenty of Hopper Space Necessary.—One of the most important things in brooding chickens in confinement is providing plenty of mash hopper space. This tends to prevent restlessness and feather and body picking.

Wire-screen Floor Pens.—The rearing of chickens in rooms with wire-screen floors in front of the house allows them to take advantage of the benefits of the sun's rays. Also, chicks reared on wire-screen floors usually get more exercise than those reared in battery brooders.

The wire-screen sun parlor is an outside inclosure next to the brooder house. It is usually about half the area of the floor inside. The frame for the bottom is made of 1- by 4-in. boards set edgewise and spaced 2 ft. apart. This is covered with 34-in.-square mesh-hardware cloth, made of No. 15 or 16 gage wire, 24 or 48 in. wide, the narrow width being pref-

erable. The frames may be made in sections, the size depending upon the number of birds to be accommodated. For a 10- by 12-ft. brooder house, a frame 6 by 8 ft. is used. Front and end panels are 24 in. wide and are made of 1- by 3- or 4-in. strips, covered with 1-in.-mesh poultry netting. The top panels may be made 2, 3, or 4 ft. wide. The front top panel is hinged so it can be opened easily when desired. The floor of the screen sun parlor may be placed 10 or 20 in. aboveground, so that the droppings can be removed by a scraper, or the frame may be set close to the ground and removed during the process of cleaning.

In order to insure that all the birds take advantage of the sun parlor, they should be fed and watered in it or be driven into it regularly once daily and shut in for a half hour, besides having a chance to go out when they please. The mash troughs should be protected from rain by slanted boards, hinged so as to turn up when feed is being put into troughs.

REARING BROILERS AND CAPONS

It has been pointed out previously that most of the day-old chicks that are produced each year are raised primarily for the purpose of replacing hens that are culled from the laying flocks. The surplus cockerels that are raised each year are sold as broilers, fryers, or roasters depending largely upon the prices that prevail for these different classes of poultry at the time they reach the different ages or sizes. Aside from this available supply of market poultry, to say nothing of the large supplies of hens that are marketed annually, there has developed in the United States a very important broiler-producing industry. Then, again, the production of capons has assumed a role of some importance. Broiler and capon rearing represent two forms of specialized poultry production.

Broiler Raising a Specialized Industry.—The development of the broiler industry represents one of the phases revealing the extent to which the poultry of the United States has become specialized during recent years. In the early development of the poultry industry, fresh poultry was ordinarily available from the fall of the year to the latter part of January. It is natural to expect, therefore, that a specialized industry would be developed whereby fresh dressed chickens would be made available to consumers during the time that other forms of fresh chickens are not available. The production of broilers has filled this need.

Breeds for Broilers.—The methods of brooding and rearing broilers either on range or in confinement have already been discussed, so that there remains at this time only the question of breeds suitable for broiler production, the matter of feeding broilers being discussed in subsequent chapters.

The question of breeds is of importance in the problem of rearing broilers, inasmuch as it has been shown from practical experience that

broiler production is usually more profitable when Plymouth Rock, Rhode Island Red, or New Hampshire broilers than when White Leghorn broilers are reared. Then, again, since the New York City market sometimes pays a higher price for barred broilers, there is frequently a premium on purebred Barred Plymouth Rock or crossbred broilers having barred plumage. The result has been an increase in the production of crossbred broilers in which, for the most part, Barred Plymouth Rock males are mated to New Hampshire or Rhode Island Red females. In these crosses

FIG. 85.—In the commercial broiler-producing sections of Maryland, stove brooders are used almost exclusively. (*U. S. Dept. Agr.*)

all of the progeny, both males and females, are barred so that a premium is often received over other kinds of broilers reared.

The parental stock used for the production of broilers, whether crossbreeding is practiced or not, should be selected most rigidly on the basis of vigor, good body size, and good body type, the males and females having broad shoulders, good depth of body, and prominent breast development being preferred. Crossbreeding usually promotes more rapid growth in the crossbred progeny during the first 10 or 12 weeks than in purebred progeny; but for best results in crossbreeding, the parental stock should be very carefully selected.

Capon-production Problems.—In many of the larger cities there are good markets for large roasting chickens. The largest size for roasting

is obtained when the cockerels of certain breeds are castrated. A castrated chicken is known as a "capon," and since capons attain their maximum size when about 8 to 10 months of age, they are ready for market after the Christmas holidays, when other forms of fresh-killed young poultry, except broilers, are scarce. Capons retain the tenderness of the meat characteristic of young cockerels. Some poultrymen hatch chicks in December and January so that their capons are ready for the Thanksgiving and Christmas markets. A special set of instruments is necessary for caponizing, and several different makes are made by manufacturers.

Breeds to Caponize.—The largest capons are obtained from such breeds as the Jersey Black Giant, Langshan, and Brahma. These breeds, however, are slow to mature and will hardly develop in time for the holiday season unless hatched early. Plymouth Rocks, Rhode Island Reds, Wyandottes, and Orpingtons make excellent capons and can be brought to prime condition in 7 to 10 months.

Age to Caponize.—Healthy, vigorous cockerels should be selected, and the operation should be performed before there is much sign of comb development, birds from 1½ to 2½ lb. in weight or from 8 to 12 weeks of age being most desirable. The cockerels should be placed in clean crates without litter and kept in a comfortable place without water or feed for a period of 12 to 24 hr. This starvation period is very important, for the operation is most easily performed on properly starved birds, and there is usually much less bleeding.

How to Caponize.—Caponizing should be done on a bright, sunny day. Set up a barrel or two egg cases as a table on which to work, or construct a table if large numbers of cockerels are to be caponized. A crate containing the cockerels should be close at hand, and another empty crate should be provided to receive the capons after the operation. The following instructions are adapted from suggestions given by the Extension Poultry Specialist of the New Jersey Agricultural College:

The cockerel should be fastened firmly to the caponizing board or table by means of straps. One strap should be placed around the wings close to the body, the end drawn through the ring, and the strap fastened to the board by means of some slots and a screw eye. The other strap should be placed around the legs above the hock joint and, after the bird is in position, should be fastened in the suitable slot. In securing the bird to the board, the left side should be next to the board with the right side of the bird facing the operator. Since the incision is made between the last two ribs of the bird, a few feathers should be plucked from this region, thus exposing these ribs. This area should be dampened, and the surrounding feathers should be soaked thoroughly so that they are held back out of the operator's way and do not obstruct his view.

In making the incision, the knife should be held firmly between the thumb and forefinger, only about ¼ in. of the blade being exposed. Held in this manner, it is hardly possible to cut so deeply that the intestines are injured. With the forefinger of the left hand, locate the last two ribs which lie just in front of the hip joint. Draw the skin back toward the hip and place the knife between the ribs approximately ½ to ¾ in. below the backbone. An incision about 1 in. long is made by drawing the knife toward the operator, being careful to follow the curve of the ribs.

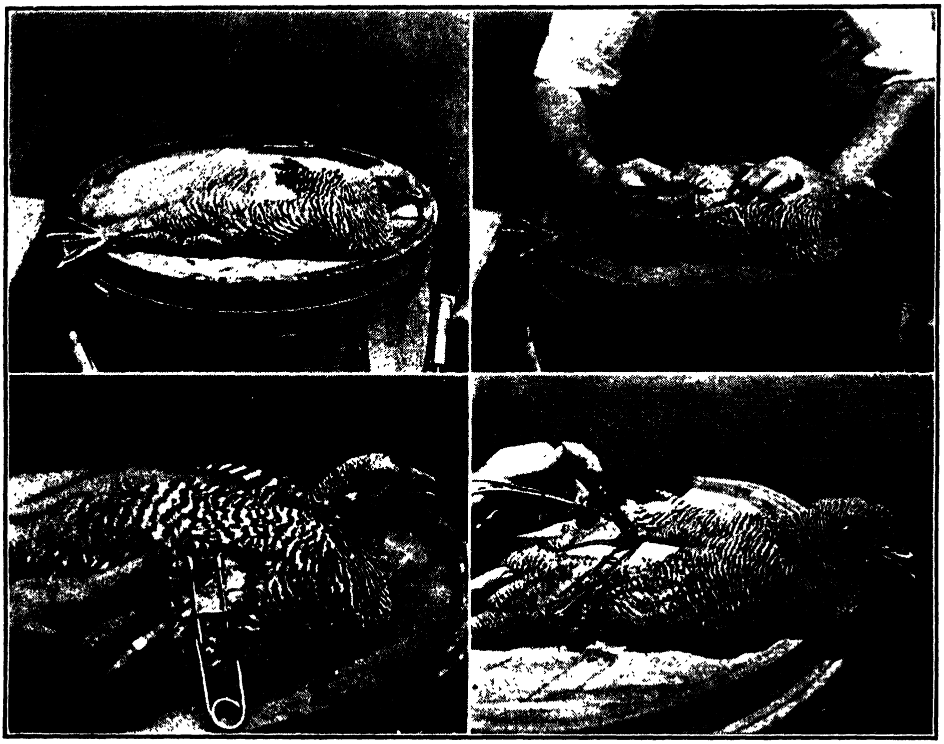


FIG. 86.—Upper left, the cockerel in position for caponizing, with feathers removed for making the incision. Upper right, making the incision. Lower left, the spreaders inserted and a probe inserted to locate the testes. Lower right, removing the testes. (*U. S. Dept. Agr.*)

The spreader should then be inserted, and the incision opened as far as possible without tearing the flesh. With the tearing hook, tear the thin membranes that cover the intestines, but carefully avoid hooking the intestines. The upper testicle can then be observed lying just below the front end of the kidney and close to the backbone.

In birds of proper size, the testicle will be about the size of a grain of wheat and usually deep yellow, although at times the color may be gray or even black. The lower organ lies just underneath the upper one and may be seen by raising the upper one with the probe. A large artery

will be observed running between the two; should this be punctured during the removal of the organs, death will result. With the jaws of the removers slightly open, reach underneath the lower testicle and gently move the instrument upward, allowing the organ to slip between the open jaws. Being sure that the entire organ is within the remover and that no blood vessels have been grasped, slowly pull the instrument out of the body cavity with a twisting motion until the organ is severed from the body. Next, remove the upper testicle in a similar manner.

Should difficulty be encountered in attempting to remove both organs from one side, the upper one should be removed, and the bird turned over and operated on from the left side. It is essential that the organs be removed intact, for if the wall of the testicle is ruptured and a portion allowed to remain in the body cavity, a "slip" will result.

The fact must be appreciated, of course, that capons do not necessarily grow faster than cockerels, so that in order to gain any particular advantage over the production of roasters, capons must be kept for a longer time, or a higher price should be secured. The impetus given to the production of broilers "out of season" has resulted in a decreased demand for capons.

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CHAPTER VII

HOUSING AND YARDING PRINCIPLES AND PRACTICE

The primary purpose of housing poultry, whether it be growing chickens or adult stock, is to provide for the comfort of the fowls at all times and in all seasons. Unless the growing stock is kept comfortable day and night throughout the growing season, it will not attain optimum growth; unless the laying stock is maintained in comfortable quarters throughout the laying season, maximum results in egg production cannot be secured; and unless the breeding stock is kept most comfortable throughout the breeding season, best results in fertility and hatchability of eggs cannot be realized.

FACTORS DETERMINING SATISFACTORY HOUSING

In the extremely southern sections of the United States maximum housing comfort for poultry implies that they are given reasonable protection from the enervating temperatures that frequently prevail during the summer months. In the nothern sections of the country housing comfort implies that steps have been taken to provide against extremely low house temperatures during the winter months and extremely high temperatures during the summer months. The factor of outstanding importance in housing is to provide against extreme variations in house temperature from day to day and from season to season.

Importance of Good Location.—In order that comfort may be provided inside the house it must be properly located so as to provide for the proper circulation of air and at the same time avoid unnecessary exposure to the wind and sun.

A southern well-sheltered slope which offers good air and water drainage is desirable. Although sloping ground is desirable in order to provide for good water drainage, there are many farms and poultry plants where the ground is flat, and under such circumstances gravel should be hauled to the location where the house is to be built to make a slight knoll. In some sections an eastern or southeastern exposure may be preferable, particularly if the prevailing winds are from the west or northwest. The trees that shelter the house should not be too close to the house or too low; otherwise the soil under the trees is liable to remain damp and harbor disease organisms. Proper air drainage is very important, and for this reason the poultry house should not be located on low ground because

cold damp air tends to settle in low places. Where the fowls are allowed outdoors, the nature of the soil in the vicinity of the poultry house is a matter of importance, the best soil being a sandy loam which provides for adequate water drainage and is suitable for growing grass or other green crops.

In building a two-story or higher house it is desirable to locate the house at the edge of a knoll in order that arrangements may be made in the way of an approach to the second floor for delivering feed.

A Convenient House Necessary.—All poultry houses must be convenient in two respects—from the standpoint of location and, on the inside, from the standpoint of tending the house.

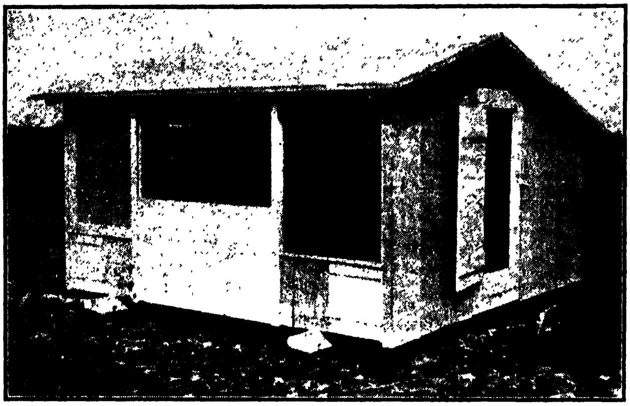

FIG. 87.—A 12 by 12 ft. colony brooder house recommended for use in Connecticut, equipped with celo-glass windows which swing inward. (*Acetol Products, Inc.*)

Where yarding is provided for growing chicks or adult stock the poultry houses must be located at some distance from other buildings, but they should not be so far away as to cause the birds to be neglected. At the same time, the saving of daily labor in tending the birds is an important point to be kept in mind in the location of several houses on the poultry plant.

The house itself must be convenient from the standpoint of adjusting windows and ventilators and caring for the birds. Simplicity of construction should always be kept in mind.

Durability of Service Most Desirable.—It is a waste of money to build a poultry house more expensive than necessary to provide for the optimum comfort of the birds. On the other hand, it is false economy to build a cheap house that can never be expected to keep the birds comfortable. The important factors in determining the cost of construction are the health and comfort of the birds, and although the original cost of construction is an important item it is a wise investment to build a durable house that will remain in good condition for several years without undue expenditures in repairs and in the cost of upkeep.

The manner in which poultry houses are constructed is of great importance not only from the standpoint of their usefulness but also with respect to providing comfort for the birds. A poorly constructed house is a poor investment, first, because its period of service is liable to be limited and, second, because it is not likely to give good results. Good materials and good workmanship are necessary requisites in the construction of a poultry house that is intended to give satisfaction.

House Should Be Easy to Disinfect.—The watchword of every poultry raiser should be to do everything possible to prevent the occurrence and spread of poultry diseases. Since the poultry house, where the birds naturally congregate, is liable to be a means of spreading filth-borne organisms, it is apparent that the house must be kept as clean as possible. For this purpose, ease of disinfection of all parts of the interior of the house is very important. Fixtures and appliances within the house should be movable, and the construction of the house should be such that all parts may be thoroughly cleaned and properly disinfected.

ESSENTIAL HOUSING REQUIREMENTS

In order that the poultry house may give the most satisfactory service it must provide the following requirements: (1) adequate ventilation, (2) moderate temperatures, (3) dryness, (4) abundance of sunlight, (5) properly installed artificial lights, (6) adequate floor space per bird.

Providing Adequate Ventilation.—The proper ventilation of poultry houses is necessary for the purpose of removing moisture and to provide the birds with fresh air. Since drafts in the poultry house should always be avoided, it is necessary to provide a ventilation system that will provide fresh air and also cause a circulation of air within the house so that the house may be kept reasonably dry, for the humidity of the air in the house is affected not only by temperature but also by air circulation, which, in turn, is affected by the ventilation of the house.

In the case of chickens reared in colony houses on range, the problem of providing adequate ventilation for the houses is not a difficult one, except at night during the hot summer months. In most sections of the United States the windows in the front of the brooder house should be removed during the hot summer months. Ventilators should be provided under the eaves on the north side of the house, and these should be kept open during the warm season to allow the warm air to circulate and pass out of the front of the house. Summer shelters, of course, are a good solution of the ventilation problem in the housing of growing stock. At any rate, poultrymen should always keep in mind that night comfort is an important factor in obtaining optimum growth during the growing season.

The proper ventilation of the laying house is of the greatest importance in providing comfort for the laying stock during the hot summer months

in all parts of the country and during the cold winter months in northern regions.

Good summer ventilation of the laying house is frequently obtained by having ventilators under the eaves on the north side of the house, or in some sections of the country all four sides of the house are opened. In the case of single-story houses, the insulation of the roof helps to keep the house much cooler during the hot summer days and nights.

The most difficult problem in the ventilation of the laying house is that of providing maximum comfort for the laying stock during the winter months, when the outside temperature frequently fluctuates greatly and

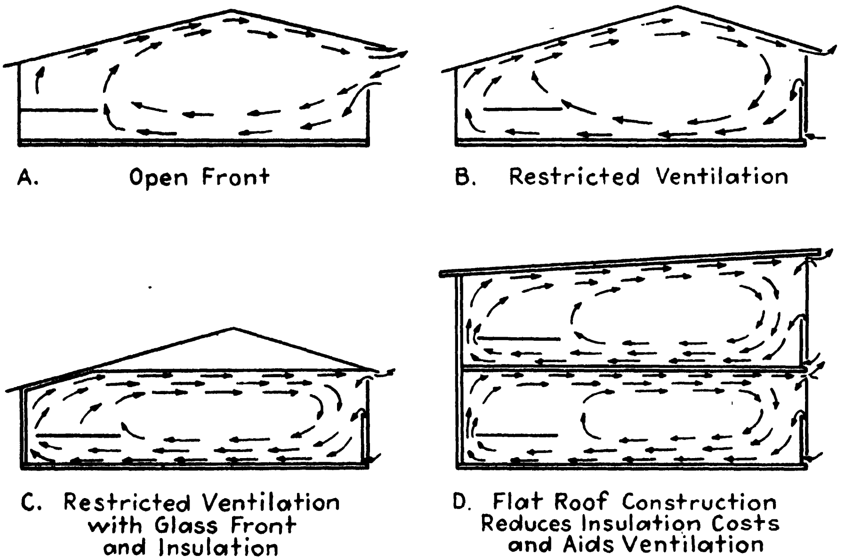

FIG. 88.—Showing different methods of ventilating poultry houses. (*Jones*, 1935.)

the inside of the house is apt at times to be very cold and damp. When the wind is not blowing, it is necessary to have a difference of temperature inside and outside the house in order to have air circulation inside. For this purpose the house must be properly insulated. When the wind is blowing, it is necessary to have the house closed sufficiently to prevent drafts from sweeping across the floor, and still there must be sufficient ventilation to promote the recirculation of air within the house for the purpose of equalizing the temperature and keeping the litter dry. By properly insulating the house and by restricted ventilation during cold weather, the difference in temperature inside and outside the house is increased, the loss of heat given off by the birds is retarded, the recirculation of air is increased, and a dry, comfortable house of moderate temperature is obtained.

The hen breathes much more air in proportion to body weight than the larger domestic animals, approximately three times as much as the

cow. According to observations made at the Southeastern Agricultural College at Wye, England, fowls at rest take into their lungs an average of 1 pt. of air per minute, or $1\frac{1}{2}$ cu. ft. per hour. The laying hen, therefore, requires relatively large quantities of oxygen or fresh air, and, of course, relatively large quantities of carbon dioxide are eliminated. From observations made at the Illinois Agricultural Experiment Station it has been computed that a hen on full feed weighing approximately $4\frac{1}{2}$ lb. liberates approximately 50 liters of carbon dioxide every 24 hours. In most poultry houses the carbon dioxide output is not a serious problem because the cubic contents of the house are relatively large as far as the birds are concerned, and most of the carbon dioxide is dissipated through cracks, crevices, and openings in the house. Moreover, the Iowa and

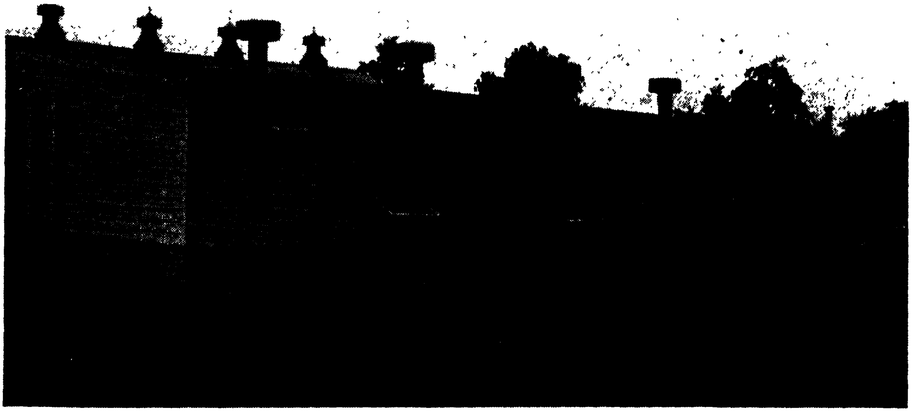

FIG. 89.—Providing summer ventilation by means of hinged ventilators and windows at the rear of the laying house. (*Pa. Ext. Service.*)

Nebraska Agricultural Experiment Stations have shown that laying hens can tolerate relatively high percentages of carbon dioxide in the air of houses that were fairly tightly sealed.

The Connecticut, Iowa, Massachusetts, and Ohio Agricultural Experiment Stations have found that laying houses with restricted ventilation in the front of the house during cold, damp weather prevents drafts, provides for minimum fluctuations in temperature, tends to conserve the body heat of the fowls, and promotes the recirculation of air, which tends to keep the house relatively dry. The Massachusetts Agricultural Experiment Station recommends that air circulation should be limited to openings high in the front wall, the openings being constructed so that the effects of wind and storms are reduced to a minimum.

Moderate Temperature Desirable.—Maximum comfort for the layers requires that the house be maintained at a moderate temperature, sum-

mer and winter. The problem of maintaining moderate temperature in laying houses must be considered from the standpoint of the "critical temperature" of the laying hen. This term is used to designate the environmental temperature at or below which the heat production of the laying hen will increase to prevent a lowering of body temperature. The Illinois Agricultural Experiment Station has demonstrated that the average critical temperature of hens when fasting is 62°F. Laying hens on full feed can probably stand a temperature of about 15°F. before feed energy is used for the maintenance of body temperature. It should be recalled, however, that the lower the house temperature the less is

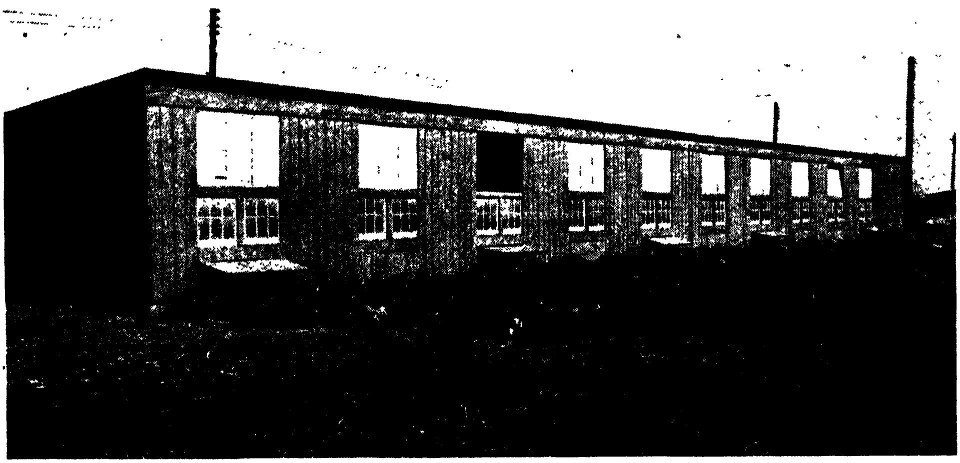

FIG. 90.—The shed-roof type of brooder house is commonly used in the commercial broiler-producing sections of Maryland. (*U. S. Dept. Agr.*)

the moisture taken up by the circulating air in the house and the damper the house. At ordinary winter temperatures the water-holding capacity of air is approximately doubled by increasing the temperature 10°.

During the hot summer months the house should be kept as cool as possible both day and night by means of adequate insulation and by the most thorough ventilation possible. During the cold winter months the object should be to avoid violent fluctuations in temperature in the house and to maintain it not below 50 and not above 70°F.

Experiments on the artificial heating of laying houses have been conducted by a number of agricultural experiment stations, but for the most part it has not been proved economically profitable. One of the difficulties encountered has been to maintain a relatively even temperature at reasonable cost, and in other cases the increase in egg production secured has not been sufficient to pay for the cost of fuel and labor involved in supplying the heat. On the other hand, the use of artificial

heat in the house when there is a sudden drop in outside temperature has been found to be very helpful in preventing a sudden drop in egg production. Brooder stoves or hot-water heating systems, with pipes laid in sand under the surface of concrete floors or along the back of the laying house, are sometimes employed. When a hot-water heating system is used, a small electric pump is necessary to circulate the water. The artificial heating of laying houses not only tends to equalize the temperature in the house during cold snaps but also tends to keep the floors of the house dry.

Before an artificial heating system is installed, it is recommended that an engineer be consulted.

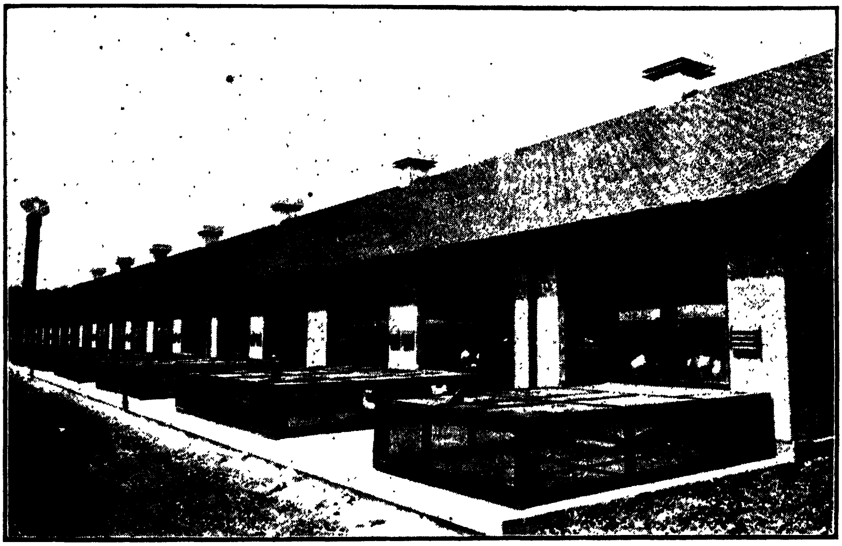

FIG. 91.—A continuous brooder house, with wire-screened sun porches on a concrete slab along the front of the house. (*Pa. State Coll. Agr.*)

Dryness Important.—Although the results of experiments at the Ohio, Iowa, and Nebraska Agricultural Experiment Stations have demonstrated that egg production may be maintained at a satisfactory level even when the air in the laying house is relatively humid, nevertheless dryness is important particularly with respect to the floor and litter. A damp floor is objectionable in cold weather, and damp litter is objectionable from the standpoint of feeding scratch grain. A damp floor and litter are also conducive to the spread of poultry diseases.

At the Illinois Experiment Station it has been observed that fowls normally drink relatively about twice as much water as do the larger classes of livestock. Relatively large quantities of water are eliminated by the fowls, and the condensation of moisture from the air of the house in cold weather frequently adds to the difficulties of keeping the litter

dry. The condensation of moisture on the floor, walls, and ceiling is greatest in houses that are not insulated, because there is less difference in temperature between the inside and the outside of the house than in houses that are insulated. The proper degree of dryness in a house is obtained, therefore, by a proper system of ventilation in a properly insulated house.

Sunlight in the House Desirable.—Sunlight in the house is desirable not only because it brightens up the house and makes the birds "happy" but also because it tends to keep the house dry and is a good germicide, being effective in destroying disease organisms. Moreover, it has been demonstrated that sunlight contains something besides vitamin D, as a

FIG. 92.—Interior view of laying house showing screen frames lowered to keep the birds off the droppings boards. (*American Poultry Journal.*)

source of which cod-liver and other fish oils are sometimes fed to birds when they are confined. All poultry houses should be so designed as to permit the admission of as much sunlight as possible.

Installing Artificial Lights.—In many parts of the country the number of hours of daylight during the late fall and early winter months is much less than during the summer months. The laying hen's working day is thus reduced, egg production is thus retarded somewhat, and feed consumption is not so great as it otherwise would be. The use of artificial light does not of itself lead to increased feed consumption, but the rays of light activate the reproductive or laying organs, and as a result of stimulated egg production more feed is consumed. The use of artificial lights enables the birds to meet the increased demand for feed. In many respects, therefore, the use of artificial sunlight makes up for the deficiency of natural sunlight.

The most practical way of lighting laying houses artificially is by the use of electricity. Electric-light bulbs are suspended from the roof of the laying pen in such a manner as to give the maximum amount of light on the floor and some light on the roosts; otherwise the birds will not leave the roosts and cannot get back to them when the light is turned off at night. One 40-watt bulb should be used for each 200 sq. ft. of floor space, the bulbs being placed not more than 10 ft. apart. The proper height of the bulb depends upon the depth of the house and the height of the roosts. Reflectors 4 in. in depth and 16 in. in diameter should be used to disperse the light properly.

In case lights are used at night, a dimming system must be provided, one set of bulbs of very low power being used on a two-circuit system. The bright lights are turned off first, leaving the dim ones on for about 15 min. to enable the birds to go to roost. Automatic switches to turn the lights on and off are on the market, or a homemade alarm-clock switch may be devised.

Adequate Floor Space per Bird.—The amount of floor space required per bird is very important in relation to the results secured with growing chickens and adult birds. The floor-space requirements for successful rearing have already been discussed in the previous chapter.

In the case of laying hens, the consensus of opinion is that Leghorns require approximately 4 sq. ft. of floor space per bird, and heavy breeds, such as Plymouth Rocks and Rhode Island Reds, approximately 4¼ sq. ft. per bird. The Washington Agricultural Experiment Station recommends the number of layers to be housed in the following sizes of houses:

Size of house, square feet	Leghorns	Heavy breeds
20 × 20 = 400	100	90
30 × 30 = 900	300	275
24 × 24 = 576	190	175
20 × 30 = 600	200	180
20 × 75 = 1,500	500	450
20 × 130 = 2,600	1,000	800

The size of the building will be determined by the need, the number of hens to be housed, and whether they are to be confined to the building or allowed free access to range. The smaller the house unit the more square feet required per hen; the larger the unit the fewer square feet required per hen. The building should be filled to capacity in winter and should never be crowded in summer.

Colony houses accommodating from 30 to 50 hens are about as large as can be moved easily, but larger numbers may be kept in one flock in a long house. Flocks of 100 to 500 are well adapted to average conditions

for the production of market eggs. Large flocks require less labor, fewer fences, and a lower house cost per bird than small flocks, but there is a greater risk of disease, and the individual hen receives less attention. It is for this reason, as well as the fact that the smaller the laying unit

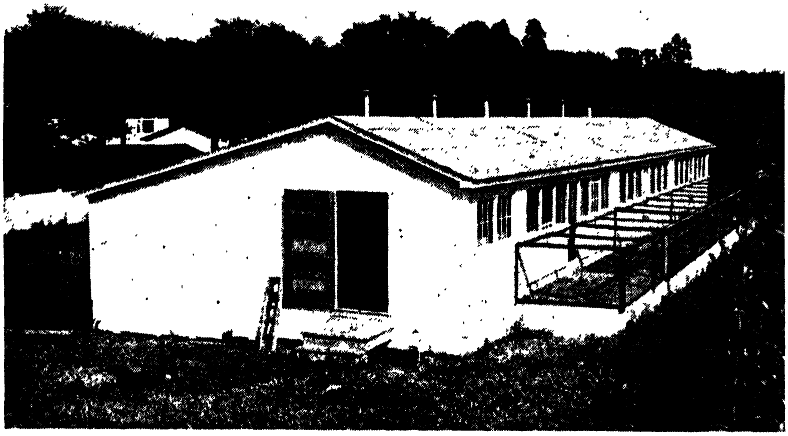

FIG. 93.—Two-thirds span "Barracks" house. (*Jones*, 1935.)

usually the better the egg production per bird, that units of 250 layers are regarded as the maximum number that should be kept together.

TYPES OF POULTRY HOUSES

There are several types of poultry houses, differing as to (1) shape and size, (2) the purpose for which they are intended, and (3) style of roof. At the same time, it should be pointed out that this is not a rigid classification of poultry houses, because in many cases the same house is used for different purposes; a large house may be divided into several units each of which serves the same purpose as a small house, and the style of roof may make a considerable difference in providing for the comfort of the birds. The classification of houses given above, however, is convenient for the purpose of calling attention to the different types of poultry houses that are constructed.

Size and Shape of House.—Houses for poultry of different ages vary according to the size of the flock to be housed and the number of units into which the flock is divided. The smallest size of house usually used is for a breeding pen of about 15 birds or a brooder or rearing house for a colony of about 150 chicks. Many of these small houses are portable in order that they may be moved to different locations from time to time in order to provide new range. Many brooder houses and practically all laying houses are stationary and vary in size from small houses each about

20 by 20 ft. to large ones each about 20 or 30 ft. wide by several hundred feet long.

Birds housed in stationary houses are kept confined, allowed on sun porches, or allowed on range, in which case yards should be provided.

With the development of modern feeding practices, which make it possible to keep laying hens confined the year round, an increasing number of poultrymen use two- to four- and five-story buildings for the layers. Barns, dairy stables, and even silos have been converted into laying houses. The use of such large houses reduces the labor required to manage large flocks as compared with keeping them in single-story houses. Housing costs per bird are reduced, including lessened costs for insulation.

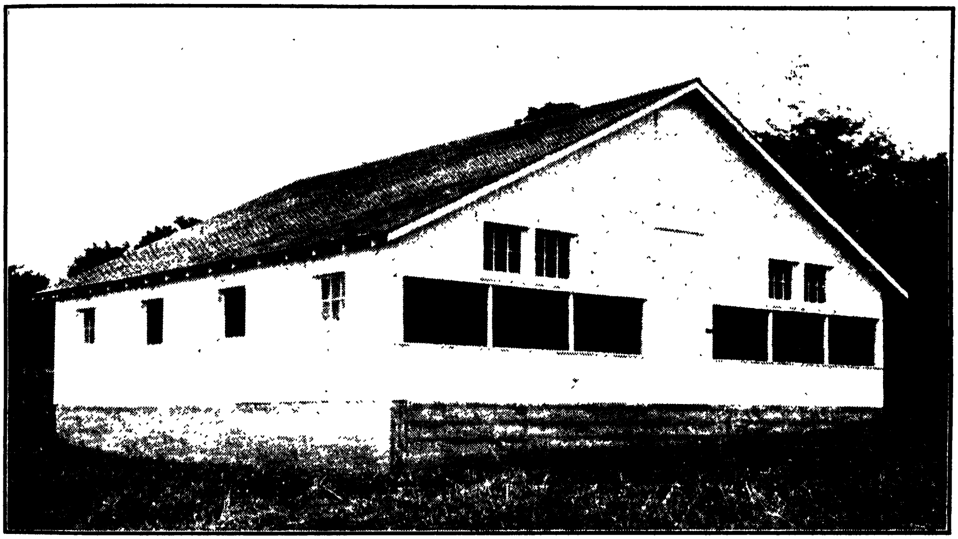

FIG. 94.—The Missouri straw-loft laying house, 30 by 30 ft. The gable is filled with straw to absorb the dampness, thus tending to keep the house dry in winter and cool in summer. (*Mo. State Coll. Agr.*)

Multiple houses also simplify ventilating problems and make it possible to maintain more uniform temperatures in summer and winter. Where proper environmental conditions are provided for the laying stock, two- to five-story houses give satisfactory results.

The shape of the poultry house should be considered in relation to its size. The smaller the house the less width is required, but for practical purposes brooder and rearing houses should be at least 10 ft. wide, and stationary laying houses for large flocks should be at least 20 ft. wide. During recent years the tendency has been to build laying houses up to 30 ft. in width.

Houses for Different Purposes.—Poultry houses are used mainly for the four following purposes: (1) brooding, (2) rearing, (3) laying, (4) breeding. On most farms and commercial poultry plants brooding

houses are used for brooding and rearing the young stock, and laying houses are used for housing the layers. Sometimes rearing houses, usually range shelters, are used in addition to the brooding houses for rearing the young stock. Breeding houses are used for the most part by poultry breeders who trap-nest their stock and carry on pedigree-breeding work.

On many farm and commercial poultry plants the poultryman is confronted with the problem of providing sufficient house room for both the new crop of pullets which should be put in the laying houses by about September and the hens that already occupy the houses. A very practical way of overcoming the difficulty is to employ what is called a "barracks" house, which can be used for brooding the chicks in the spring of

FIG. 95.—A four-story laying house accommodating several thousand birds. The layers are confined to the house from the time they enter until their usefulness for egg production is over. (*Jasper Poultry Farms.*)

the year, finishing the cockerels as broilers after the pullets have been taken to the range, and keeping the hens from the time the pullets require the laying house until the hens have completed their summer and fall egg production. Hens in heavy production during the late summer and fall are profitable because they lay large eggs, as compared with pullets, at a time when high premiums are paid. To neglect the pullets, leaving them on range after they start to lay, means that they will probably lay small eggs, lose flesh, and be less profitable than if housed at the time production starts. Another problem that often confronts poultrymen is the labor involved in brooding early chicks in colony houses. Many poultrymen would be willing to build a large brooder house if it could be kept profitably employed during the entire year. Still another perplexing problem is where to house and finish broilers when the pullets need all of the available brooder and range capacity. The barracks-house system

of management solves these problems in a way that is economical and practical.

Style of Roof.—Several different styles of roof are used on poultry houses, the most common being (1) shed, (2) gable, (3) combination, (4) monitor, (5) semimonitor. The style of roof not only affects the appearance of a house but is of importance in determining the environmental conditions that it is possible to maintain within the house.

The shed-roof house is the one most commonly used for brooding chicks and for housing laying stock. The shed roof is the simplest kind of roof to build and requires the least lumber for a given floor space in the house. In a house with a shed roof it is possible to place the windows in the front relatively high so that the space under the windows can be boarded to prevent drafts over the floor and an abundance of sunlight is

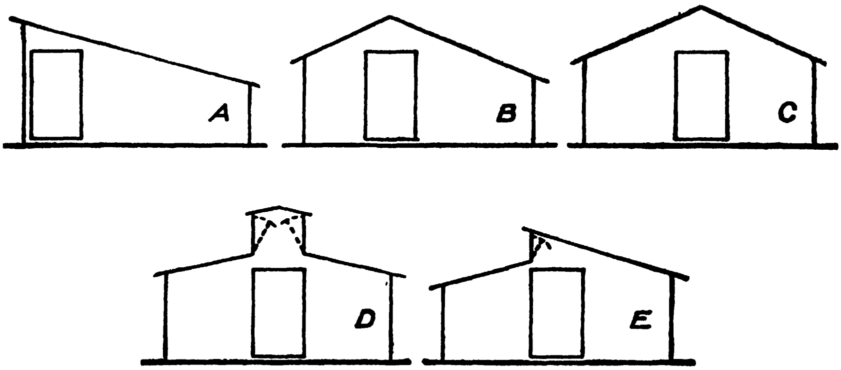

FIG. 96.—Types of roofs of poultry houses. *A*, shed roof; *B*, combination; *C*, gable; *D* monitor; *E*, semimonitor. (*U. S. Dept. Agr.*)

admitted to the house. The shed roof sheds rain water and melted snow to the rear of the house, thus tending to keep the ground in front of the house dry. The Connecticut Agricultural Extension Service recommends a very slight pitch, 1 in 24 ft., for multiple-story houses. When this type of roof is used, however, care must be exercised to provide for the snow load that may occur, and built-up roofing material should be used.

The gable-roof house is one in which the roof slopes to the front and rear from the center of the house. The center of the house being the highest makes it convenient for the attendant to work inside. If the house is just high enough at the center to allow the attendant sufficient headroom, the front of the house is apt to be rather low from the standpoint of admitting sunlight. The gable roof may be used on wider buildings than the shed roof.

The combination roof is merely a modification of the gable roof, the spans on each side of the peak being of unequal width. In most combination-roof houses the wider side of the roof slopes northward, and the narrower side slopes southward, thus enabling the windows in front to be

placed high enough to admit plenty of sunlight. The "Tolman" house, introduced some years ago, is an example of a combination-roof house in which the wider side of the roof slopes southward, thus making the front of the house quite low.

The monitor-roof house is one in which the center portion of the roof is raised for the installation of windows for the purpose of admitting sunlight from both sides. The monitor roof is used principally in wide houses which have breeding pens on both sides of an aisle running through the center of the house from end to end.

The semimonitor-roof house is one in which the roof back of the peak is raised high enough to install windows for the purpose of admitting sunlight to reach the rear of the house. This style of house, however, is often drafty and is usually difficult to ventilate properly.

CONSTRUCTING THE HOUSE

In a book of this kind it is impossible to devote space to plans and specifications of the numerous kinds and types of poultry houses that are in use. These can be secured from the various state agricultural colleges and experiment stations. In the space available for a discussion of poultry-house construction, the more important things to be kept in mind in building a house are treated briefly.

Materials Used in Constructing Houses.—Wood in various forms is the cheapest and most commonly used material for building houses. The framework consists of the sills, which support the building; the studs, or uprights, which rest on the sills; the plate, which is on top of the studs; and the roof rafters, which rest on the plates. The sills are placed on wooden posts, stones, or concrete supports or directly on top of concrete walls. Wooden posts should be from 6 to 8 in. in diameter, placed 6 to 8 ft. apart, and 2 to 3 ft. in the ground or below the frost level. Cedar, locust, chestnut, redwood, and cypress are preferable to most other woods. Concrete posts may be used in place of wooden posts and are much more durable.

Sills.—The sills may be either 2 by 4 or 4 by 4 in., depending on the size and construction of the building. Sills 2 by 4 in. are heavy enough for colony houses or those of light, single-wall construction if sufficiently supported, while sills 4 by 4 in. are used for larger buildings and for houses with double walls. Sills 4 by 6 in. are used in two-story henhouses or other large poultry buildings and should be set on edge, unless on a concrete or stone wall, when a lighter sill may be used and laid flatwise. Concrete walls are commonly used as foundations for large poultry houses, with a 2- by 4-in. sill, which is bolted to the walls. The posts or supports must be set close together if light sills are used.

Runners.—Runners 3 by 4 or 4 by 6 in. are used as sills for portable houses, which require heavy framework. Portable houses that are to be moved on runners must be braced extra well in the corners to stand the strain of moving.

Joists.—Floor joists may be of 2- by 4- or 2- by 6-in. lumber, depending on the span. They should be from 16 to 20 in. apart. If the span is over 10 ft., a center support should be used for 2-by-4 joists.

Studding.—The studding is toenailed on the sill and should be set plumb with a spirit level and braced well until sheathed. The studding is set from 2 to 4 ft. apart for the rear walls and is placed to fit the windows, curtains, and doors in the front and ends. The studs should be

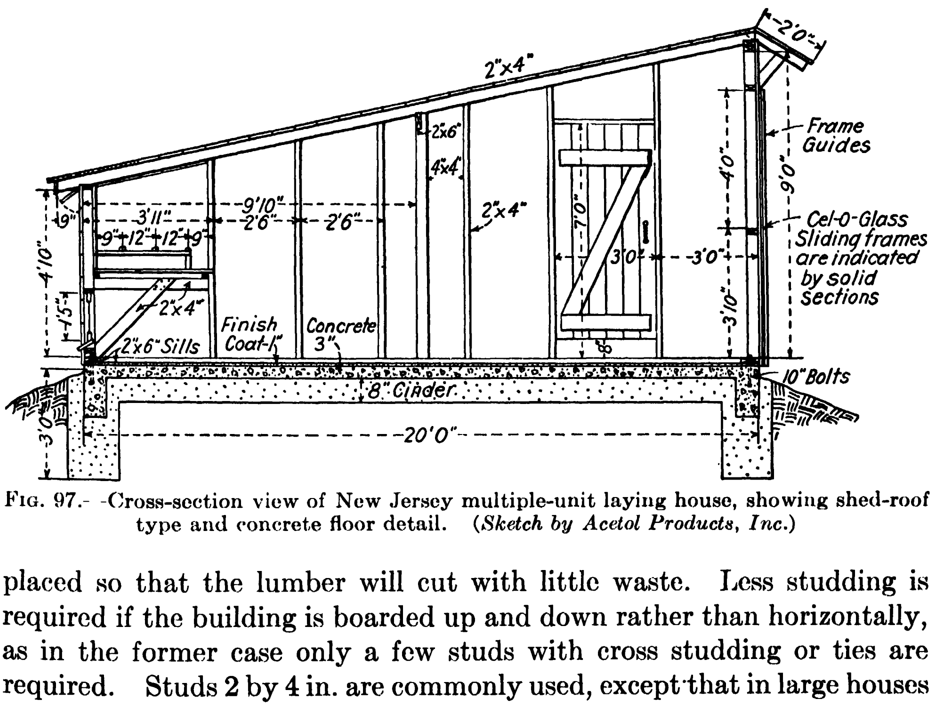

FIG. 97.—Cross-section view of New Jersey multiple-unit laying house, showing shed-roof type and concrete floor detail. (*Sketch by Acetol Products, Inc.*)

placed so that the lumber will cut with little waste. Less studding is required if the building is boarded up and down rather than horizontally, as in the former case only a few studs with cross studding or ties are required. Studs 2 by 4 in. are commonly used, except that in large houses the corner studs are generally doubled, making them 4 by 4 in.

Plates.—Plates are halved or spliced and nailed together at the joints or ends, which should be made over a post or stud. They are spiked at the top of the studding and are made of 2- by 4-in. scantling, laid flat on top of the studs, or 4 by 4 made by spiking two 2 by 4's together.

Rafters.—Rafters may be 2 by 4 or 2 by 6 in., the 2 by 4's being used only in light buildings where the clear span is not more than 12 ft., and 2 by 6's for longer spans and in climates where roofs have to bear much snow.

Purlins.—It is advisable to use purlins in buildings where rafters are more than 12 ft. long. Purlins are usually made of 2- by 4- or 2- by 6-in.

material set on edge on posts to support the roof. They are placed lengthwise of the house about midway the length of the rafters, which rest on them. In a deep house which has a wide droppings board the purlin may be placed at the front edge of the droppings board, so that the posts supporting the purlin will not be in the way in the pens.

Roofs.—In roofs that form a ridge, a board may be placed between the ends of the rafters to keep the ridge straight and even, but this is not necessary in most poultry houses. Collar beams or crossties 1 to 6 in. are used to prevent the spreading of the rafters on gable or combination roofs. They should be placed as low as possible on the rafters, so as to stiffen the frame, but not so low as to interfere with head space.

In erecting the rafters one pair may be set in position, and the rest marked from these. They should be notched only deep enough to make a snug fit and to provide good nailing on the plates, because deep notching weakens them. Rafters are usually spaced 2 ft. apart, from center to center, so that the roof boards will cut with minimum waste.

Concrete Mixtures.—Good cement and clean sand and gravel are necessary for making a good concrete mixture. A mixture for the wall foundation may be made of 1 part cement, 2½ parts sharp sand, and 3½ parts clean gravel or crushed stone. For the floor of a poultry house the mixture should be 1 part cement, 2 parts sharp sand, and 3 parts clean fine gravel or finely crushed stone.

Building the Foundations and Floors.—Except for portable houses, such as are used for brooding and rearing, practically all poultry houses should have concrete foundations and floors. Before starting to dig the ditch for the foundation, square the corners by fixing one side of the site of the proposed house. With this as a base, locate the other corner posts by using the 6-, 8-, and 10-ft. combination, measuring 6 ft. from one end of the fixed line and 8 ft. from the same end at right angles. The angle between the two lines is fixed by measuring 10 ft. from the 6-ft. mark of the fixed line to the end of the 8-ft. line, thereby making a square corner.

The depth at which the ditch should be dug for the foundation for the walls depends upon the height of the house to be built. Generally speaking, a ditch about 1 ft. wide by 2 ft. deep is desirable, the exact depth depending upon how strong a wall foundation is desired and whether or not there might be danger from heaving through freezing. Should there be any possibility of water's getting under the foundation, a row of tile should be laid at the bottom of the outside edge of the ditch, and a good drainage outlet provided. The foundation of the poultry house should be at least 6 in. thick, using a 1:2½:3½ mixture of cement, sand, and gravel, respectively. The top of the wall should be at least 10 in. above ground level.

Concrete floors for poultry houses are much more satisfactory than board floors, because concrete floors are ratproof, more durable, and can be kept more sanitary. Some poultrymen use hardware-cloth floors which lie on the concrete floor, especially for brooding chicks. The floor should have a pitch of about 4 in. from back to front. The foundation should consist of about 8 in. of fine gravel or cinders, or, if there is danger of dampness working up through the foundation and the floor by capillary action, a layer of flat tile or cinder blocks should be laid on top of the gravel or cinders. The gravel or cinders should be tamped down firmly, and a layer of one thickness of tar paper laid on top in order to help in keeping the floor dry. All danger from dampness may be overcome by pouring the concrete mixture on a thick layer of straw, metal straps supported by iron stakes being used as a support for the floor when the straw rots. There is thus formed a hollow between the ground level and the bottom of the floor; such a floor has been found to be cooler in summer and warmer in winter than many other floors.

The concrete floor should be about 3 in. thick, and the top of the floor should be about 8 in. above the outside ground level. If a 1:2:3 mixture, respectively, of cement, sand, and gravel is used it may be laid down in one operation, although some poultrymen prefer to use a 2-in. thickness of the 1:2:3 mixture and then topcoat it with a mixture of 1:2:2. The top of the floor should be finished with a wooden trowel in order to produce a smooth surface, and the final finish should be made with a light trowel. If water glass is added to the top finish of the floor it will be smooth and easy to clean. The floor should be kept wet for several days after being laid in order to permit the concrete to harden properly. If the concrete floor is laid down in cold weather, drying may be hastened, and some protection from frost provided by adding 2 lb. of calcium chloride for each bag of cement, first dissolving the calcium chloride in water.

Installing Windows and Ventilators.—Windows are necessary to admit sunlight and, on adjustment, to admit fresh air and provide ventilation. For the most part they should be placed high enough so that the boarding under them will protect the birds from drafts. Depending upon the type and construction of the house, approximately 1 sq. ft. of window space should be provided for each 20 to 35 sq. ft. of floor space. Windows should be installed so that, when a window is closed, the sash at the bottom will lap over the boarding 2 in.; and when it is open, the sash will slide down out of sight.

Since ordinary window glass does not permit the passage of the ultraviolet rays of sunlight, and since these rays have been found to be so important in maintaining birds in good health and promote growth and egg production, glass substitutes having a wire base are often used for windows. During recent years a number of glass substitutes have

appeared on the market, some of them permitting approximately 40 per cent of the ultraviolet rays to pass through. A glass substitute should be chosen with great care and if used should be fastened to frames so arranged that it can be protected from the deteriorating effects of the direct rays of the sun and high summer temperatures.

Insulation Extremely Important.—The proper insulation of the walls and roofs of poultry houses is extremely important from several standpoints. (1) In cold weather, heat is conserved so that the birds require less feed and are kept more comfortable. (2) In hot weather, the inside

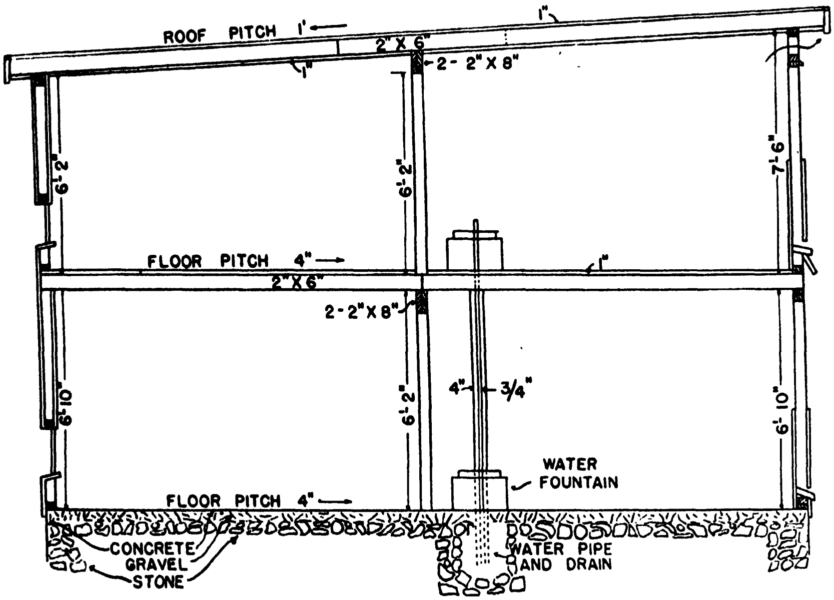

FIG. 98.—Showing the cross-section view of the Connecticut 24 by 24 ft., two-story laying house. (*Jones*, 1935.)

temperature is considerably cooler, thus keeping the birds in greater comfort. (3) The house temperature varies less from day to day than in an uninsulated house, thus promoting better growth in chickens and egg production in hens. (4) Insulation establishes a greater difference in temperature between the inside and outside of the house, thus promoting better circulation of inside air and better ventilation and a drier house than when there is no insulation.

A very satisfactory method of insulating the walls of the house is to use ordinary sheathing on the inside with building paper next to the studs. Still more effective insulation is secured if the space between the outside wall and the sheathing is tightly packed with shavings. Several of the composition insulating materials on the market are not satisfactory for insulating walls, because chickens tend to pick holes in them.

For roof or ceiling insulation, composition boards are very satisfactory. For buildings with high roofs the ceiling should be placed as low as possible and still allow the attendant to work comfortably in the house. The so-called "straw loft" is another method of insulating the roof. The straw is supported by wire netting and should be from 12 to 18 in. deep, and at the ends of the house above the straw there should be ventilators to allow air to pass out from above the level of the straw.

The Roof Should Be Durable.—The roofing material used should provide against leakage and should be sufficiently durable to last for several years. For most types of roofs, especially those with a good pitch, three-ply roofing material of good grade is satisfactory. For roofs with a slight pitch a built-up roof is a practical necessity, as pointed out by the Ohio and Connecticut agricultural extension services.

A built-up roof is made by laying several thicknesses of roofing paper over wood sheathing, which should be made of tongue-and-groove boards in order to prevent the wind from blowing through to loosen the roof. The first layer of roofing paper, which should weigh 60 lb. per square, is heavier than the others and is laid at right angles to the sheathing, being nailed down tightly by using tin-cap spacing nails. The other layers of roofing paper, varying from two to four in number, are cemented down with a hot-asphalt compound.

Comfortable Roosting Arrangements.—Many poultrymen fail to realize that growing and adult chickens spend approximately one-third of their time on the roosts. Comfort during the night is probably just as important as comfort during the day for growth and egg production. For growing chicks, roosts should be provided when the chicks are 3 or 4 weeks of age, crowding on the floor being avoided and the chicks provided with more air. For laying hens, the roosts are usually placed toward the back of the house 6 to 8 in. above the droppings boards or collecting pans or over a pit for collecting the manure deposited by the birds during the night. The roosts may run lengthwise or crosswise of the house, and if droppings boards are used they start from the rear wall of the poultry house and should be about 3 ft. above the floor. Droppings pits instead of droppings boards are sometimes used, in which case the roosts are about 2 ft. above the floor.

Scantlings 2 by 3 or 2 by 4 in. with the narrow edge up and upper edges rounded off make good roosts. For Leghorn hens a roosting space of 7 in., for Plymouth Rocks 10 in., and for Brahmas about 12 in. should be allowed. The roosts should be placed about 13 to 15 in. apart for Leghorns and 15 to 18 in. apart for Plymouth Rocks, leaving about 12 in. from the outside roost to the outside of the droppings board or pit. Wire netting 1½ in. mesh No. 16 gage should be placed immediately beneath

the roosts to prevent the birds from picking at and treading on the droppings.

HOUSING EQUIPMENT AND APPLIANCES

Properly equipping the houses and the providing of certain appliances are necessary for the efficient management of the growing and adult stock. Oftentimes the installation of suitable equipment and the use of simple appliances saves much labor and proves to be one of the best investments in management practice. Moreover, with proper equipment in the brooding and laying houses, the birds are given a better chance to grow properly and lay well than where there is inadequate equipment. Then, again, the use of a few appliances aids in keeping the houses clean.

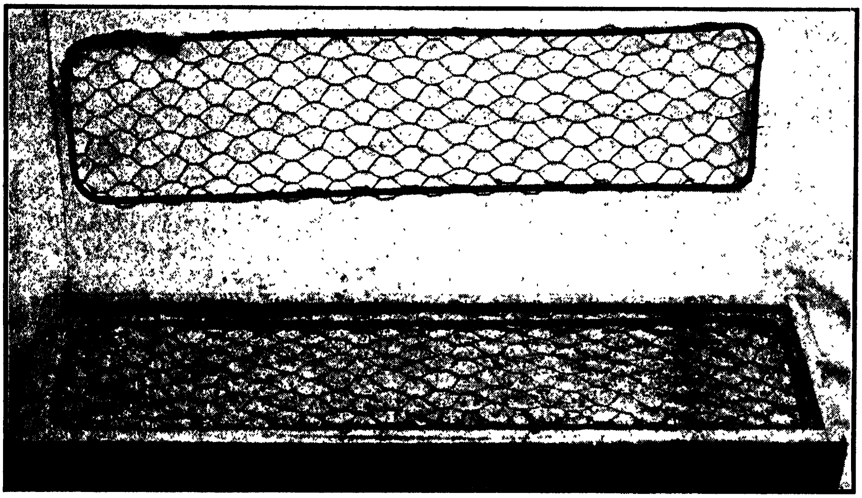

FIG. 99.—Open trough for feeding mash to chicks. The grid, shown above and in place, permits chicks to have easy access to the mash but prevents waste from scratching. *(Ohio State Agr. Exp. Sta.)*

Grain Bins.—In order to save labor in transporting scratch grain and mash to the brooding and laying houses, it is often desirable to have a grain bin either in or adjoining the house. The bin should be located at least 10 or 12 in. above the floor level and should be lined with tin to prevent the depredations of mice and rats.

Mash Hoppers.—The dry-mash portion of the ration for growing chicks and laying hens should be fed in self-feeding hoppers. Self-feeders enable the birds to eat at all times during the day. The hoppers should be large enough to hold a quantity of mash and should be so constructed as to avoid any waste. Mash hoppers for growing stock used on the range must be so constructed as to prevent rain from getting into the mash, while those used in houses do not require a covering but should have a reel or other device for preventing the birds from getting into the mash or roosting on the hopper.

Wet-mash Troughs.—When wet mash is fed, a V-shaped trough is most suitable.

Feed Carriers.—Labor-saving conveniences in the way of feed carriers constitute a good investment on commercial poultry plants. A horse and wagon saves many steps in carrying grain to the various houses.

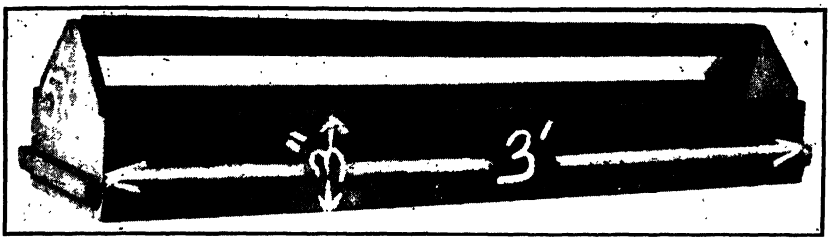

FIG. 100.—An open mash hopper with a reel to prevent the chicks from getting into the hopper and soiling the mash. Suitable for chicks after about 3 weeks old. (*Ill. State Coll. Agr.*)

Grit and Oyster-shell Hoppers.—Grit and oyster shell are fed in what are known as "open self-feeding hoppers." The essential feature in connection with the feeding of grit and oyster shell is that they be always accessible in a good location in the house.

Fresh Green-feed Hopper.—In some sections of the country, fresh alfalfa or grass is supplied as a source of green feed, and suitable hoppers in which it may be fed are very useful.

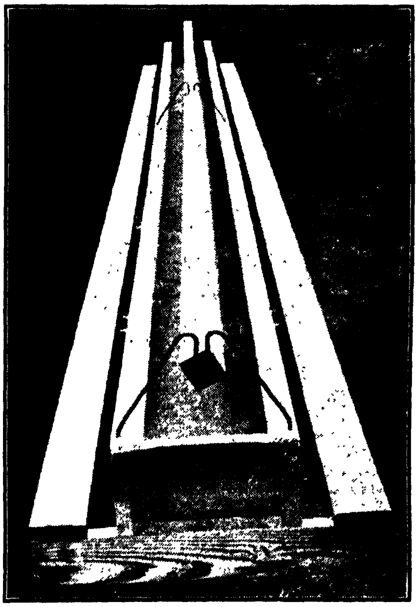

FIG. 101.—A reel self-feeding mash hopper for layers. (*Ohio State Agr. Exp. Sta.*)

Watering Devices.—Clean water should always be available for all classes of chickens. When pans and pails are used they should be so arranged that the birds cannot get into them to contaminate the water with their dirty feet. If pans for growing chicks are used, they should have a wire or slat covering so arranged as to keep the chicks out of the pan itself. For the laying stock, pails on a stand is a very convenient method of insuring an abundant supply of clean water, although laying down water pipes to carry the water to poultry houses is a wise investment, particularly from the standpoint of saving labor.

In southern and other parts of the country where there is little danger of the water's freezing during the winter months, watering pipes are

frequently conducted into the houses or to the fronts of the houses so that running water is available at all times. Usually a long watering trough is located on a platform some distance above the floor, and a float is attached to the top so that an overflow is avoided.

In northern sections of the country, provision for a watering system should be made before the laying-house floor is laid down. Water pipes should be laid down to a convenient place in each pen for locating a "dry well," which should be large enough to accommodate the water-pipe inlet and allow drainage water from the water fountain to drain away. If the soil is not well drained, special drainage to the outside of the house should be provided. In the riser of each fountain a stop and waste cut-off valve should be provided to avoid any danger of freezing. Water may be allowed to run constantly, or a pan with an automatic float valve may be provided. A wire platform for the birds and a large container below to catch the drippings and carry them into the drainage outlet will help to keep the litter in the house dry.

FIG. 102.—The interior view of a well equipped laying house. 1 and 2 are part of the ventilating system. 3 is the litter carrier running in front of the droppings board. 4 shows the nests. 5 is the watering fountain. 6 is the self-feeding mash hopper. (*Poultry Item Publishing Co.*)

In the northern parts of the country the water usually freezes in the laying houses unless it is heated in some way. Water fountains and pails have been designed which are heated with lamps, electric bulbs, and especially constructed heating elements. The use of lamps for heating the water container is not advised, because of the relative danger from fire.

Droppings-board Scraper.—The proper cleaning of the droppings boards is very important in keeping the laying house clean and sanitary. For this purpose a good droppings-board scraper is necessary.

Nests.—The nests should be constructed so that they may be cleaned readily, and there should be enough of them so that several hens do not crowd into one nest and break eggs. Boxes should not be used for nests, because the corners tend to harbor lice and mites and are difficult to clean and disinfect properly.

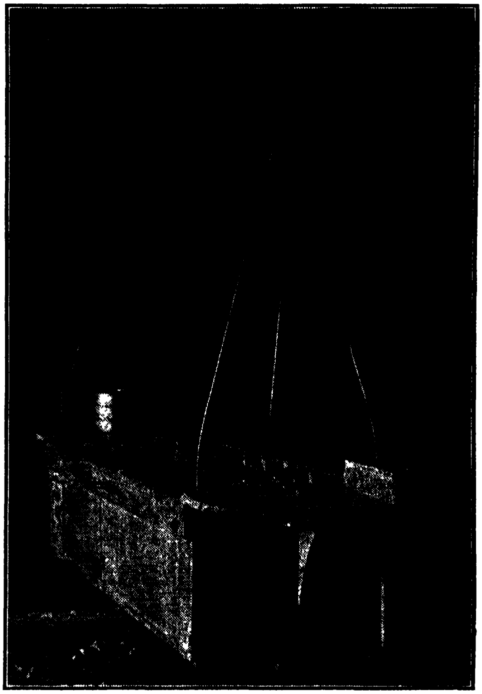

Fig. 103.—An overhead carrier for transporting feed from the feed house to the laying houses. (*U. S. Dept. Agr.*)

When pedigree breeding work is carried on, trap nests are necessary. There are different styles of trap nests manufactured by various companies, or trap-nest fronts may be purchased and attached to the nests. Trap nests should be made so that they may be cleaned readily, and they should be durable and well ventilated. The traps should be kept in perfect working order at all times. There should be one trap nest for approximately every four birds in the flock.

Egg Carriers.—On plants where several hundred eggs are gathered daily, special egg-carrying devices are often employed. They should be so constructed as to facilitate the collecting of the eggs and to avoid egg breakage. Egg pails should be well-ventilated open wire or metal pails in order to provide for the proper cooling of the eggs as soon as possible after they are gathered.

Litter Carriers.—On many commercial poultry plants, litter carriers suspended from overhead tracks are used in cleaning the laying houses and the droppings boards. Where the size of the plant justifies its use, the installation of a litter carrier is a good investment.

Broody Coops.—Coops for "breaking up" broody hens are necessary in all houses. The sooner that broody hens are broken from setting the sooner they come into laying condition again. The coop for broody hens should be so constructed that it gives the birds access to feed and water at all times. It should be easy to clean and should have a false bottom so that the droppings will not accumulate in the coop. Feed cups or troughs and water cups should be attached to the coop, because the

broody hens should be fed and watered regularly in order to get them back into laying condition as soon as possible.

Selecting Crates.—For the proper selection of breeders and layers and nonlayers, a good selecting crate is necessary. It should be strongly

FIG. 104.—A satisfactory type of self-feeding hopper for green alfalfa and other forms of green feed. (*Calif. State Coll. Agr.*)

built, easily portable, and so designed with movable ends and a sliding-top door that it provides for the most efficient selection of birds.

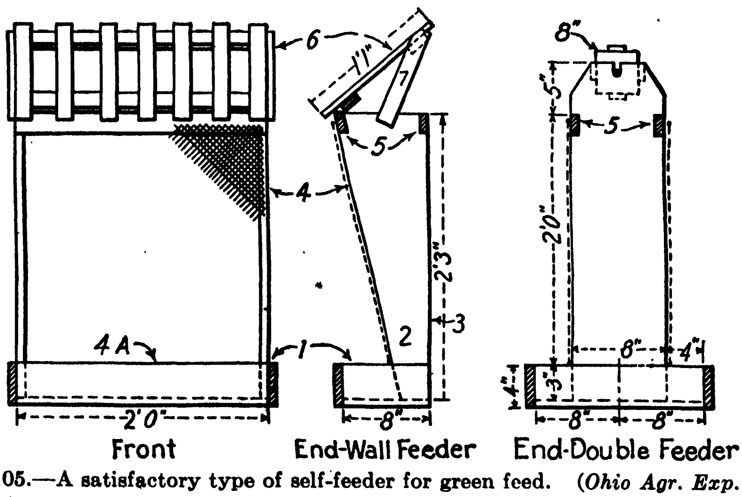

FIG. 105.—A satisfactory type of self-feeder for green feed. (*Ohio Agr. Exp. Sta.*)

Catching Hook and Net.—When it is necessary to catch an individual bird, a hook or a net may be used. The catching net is preferable to the catching hook, because there is less danger of injuring the bird.

Spray Pump.—For the proper disinfection of brooder and laying houses, a convenient and efficient spraying pump is necessary.

Incinerator.—Diseased birds that are killed and dead birds should be burned, a good incinerator being very convenient for this purpose.

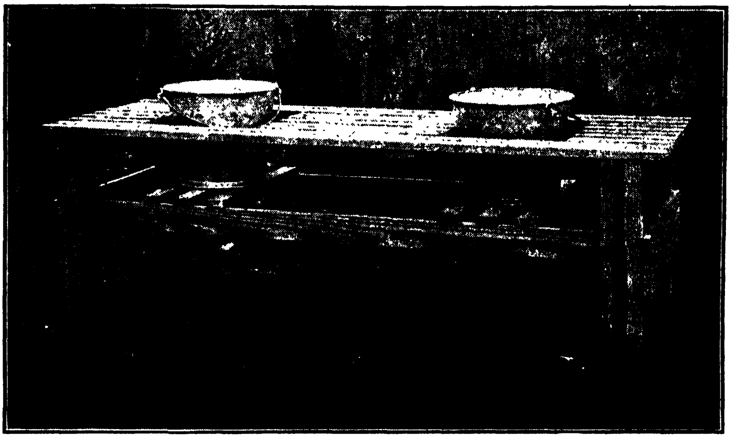

FIG. 106.—A slatted platform for the water pails for laying stock. (*Ill. State Coll. Agr.*)

HOUSE-MANAGEMENT PROBLEMS

In order to provide the birds with the greatest possible comfort while they are in the house it must be attended to with the greatest of care. A

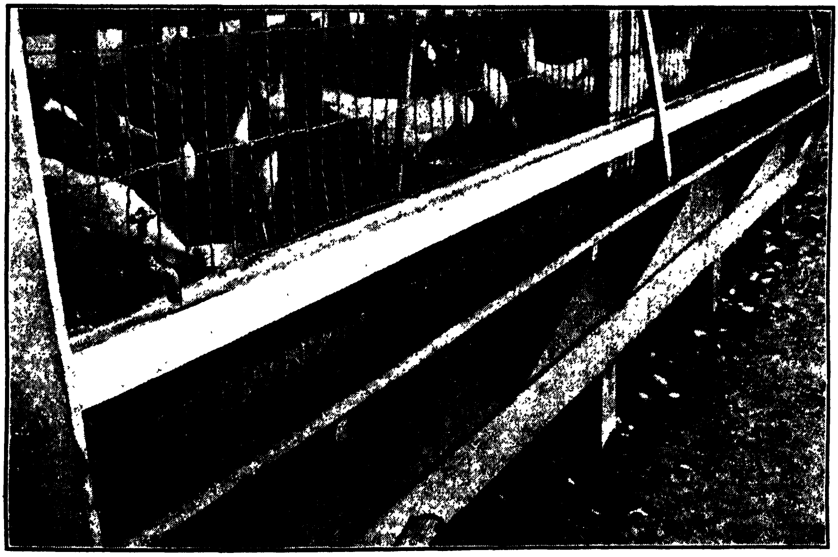

FIG. 107.—A continuous supply of fresh water is insured in this arrangement in a Washington State laying house. Milk pans are located on the inside and the mash hopper is located beneath the water trough. (*Wash. State Agr. Exp. Sta.*)

well-constructed house equipped with adequate facilities for providing maximum comfort for the birds is of little use if improperly managed.

The windows and ventilators must be properly adjusted according to the wind and weather during the winter months. Neglecting to do so even one night during a sudden drop in temperature may result in a marked decrease in egg production. Drafts should be avoided. If artificial heat is used in the laying house, care should be taken to maintain an even temperature. During the summer months the object should be to keep the house as cool as possible.

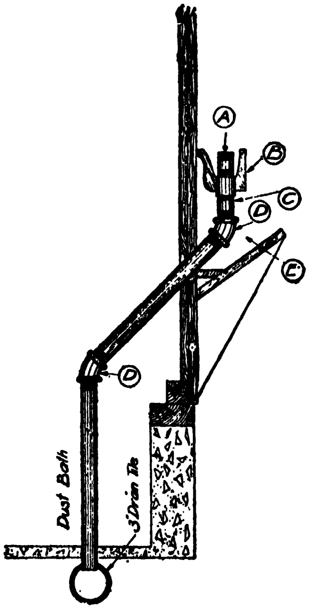

FIG. 108.—Cross section showing overflow of the running water system shown in Fig. 107. To prevent clogging, all overflow pipes are 2-in. in diameter and right-angle connections are used.

A. Loose nipple 1½ in. long which holds the water to the desired level in the trough. It is easily removed with the fingers to flush the trough.

B. Cross section of 3- by 4-in. wooden guttering with the O. G. side toward the wire front to make the feed trough more accessible.

C. 1-in. coupling which is fitted tightly into bottom of water trough and permits easy removal of nipple *A* for flushing.

(NOTE.—Arrow in illustration points by mistake to nipple below coupling instead of to coupling itself.)

D. 45-deg. elbows.

E. Lower feeding trough used for feeding wet mash and lawn grass. (*Wash. Agr. Exp. Sta.*)

The litter used in brooding and laying houses should be a good absorbent and should be kept in a reasonably sanitary condition at all times. Straw is the most widely used form of litter, although finely cut cornstalks, ground corncobs, shavings, peanut hulls, cottonseed hulls, and several kinds of specially prepared litters have been used with varying degrees of success. Damp litter is objectionable because it tends to harbor disease organisms. How frequently the litter should be removed depends largely upon the number of birds in the house, weather conditions, and the extent to which the house is properly ventilated.

Sick birds should be removed from the flock as soon as they appear, in order to prevent the possible spread of disease organisms. If a pen of birds in a long brooder or laying house becomes highly infected with a contagious disease, it should be kept isolated from all other pens until all danger of the disease's assuming epidemic proportions is over. Birds that have been purchased or returned from egg-laying contests should be kept quarantined until there is reasonable certainty that they may be safely admitted to the flock. It is good practice not to allow visitors inside houses where birds are kept on the floor.

The watering utensils and feed hoppers, especially the former, should be kept in sanitary condition at all times, for they are a constant source of the spread of disease organisms.

The droppings boards and pit should be cleaned regularly. Gypsum or acid phosphate may be sprinkled on the former to make them easier

to clean. If the manure in the droppings pit tends to develop an odor, it may be sprinkled with creosote. The manure should be hauled to land on which no chickens are allowed that year, or it may be sold, as is often done in the case of large commercial poultry plants, in a dried form to greenhouse operators. If poultry manure is to be stored in quantities before being disposed of, it should be mixed with some absorbent material such as straw, peat, or loam. Adding acid phosphate tends to reduce the loss of nitrogen because the acid phosphate combines with the ammonia as it is formed.

Since the majority of poultry diseases are filth borne, it is obvious that the poultry house should be kept clean at all times. The litter

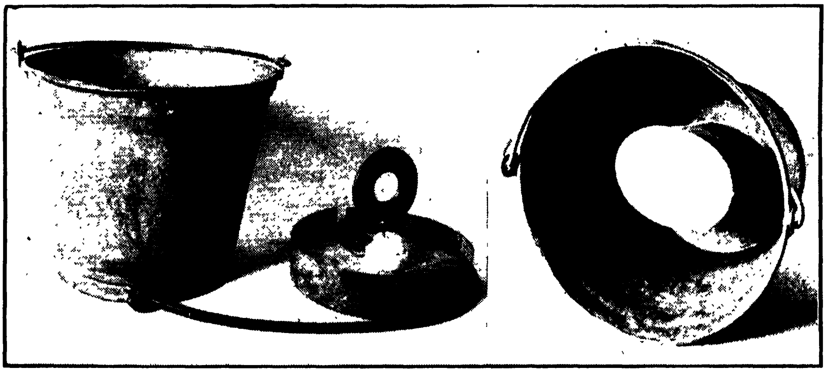

FIG. 109.—An electrical apparatus for keeping the water accessible for the layers at all times. The illustration on the left shows the base with its electrical unit and the pail into the bottom of which it fits. The illustration on the right shows the water pail with the indentation for the electrical unit. (*Ill. State Coll. Agr.*)

should be removed at frequent intervals, and the house thoroughly cleaned and disinfected with a strong disinfectant as prescribed in the chapter on Disease Prevention. Of course, the house should be put in the most sanitary condition possible before chicks or laying pullets are admitted. When the breeding flock has been tested for pullorum disease, and the reactors have been removed, the poultry house should be cleaned and disinfected. If the weather is cold, instead of using a disinfectant in a water solution, low-grade kerosene with sufficient crude carbolic acid added to it to impart a distinct odor may be used.

ALTERNATE YARDING MOST DESIRABLE

All poultrymen should realize that there are no known substitutes for sunshine and young green grass in keeping poultry in the best possible state of health and in promoting growth and maintaining egg production. Where sunshine and young green grass cannot be provided, as in the case of birds kept in strict confinement, the best possible substitutes must be provided. In the case of most farm and many commercial flocks,

however, the growing stock is reared on range, and the adult birds are given yards or allowed to roam at will.

If the staggering losses among growing chicks and laying birds that occur annually are to be reduced materially, better methods of flock management must be employed. The losses from mortality are due largely to internal parasites and diseases of one kind or another. Bare ground over which the chickens have run for some time, mud puddles, and stagnant water are the chief sources of the spread of diseases, most of which are filth borne.

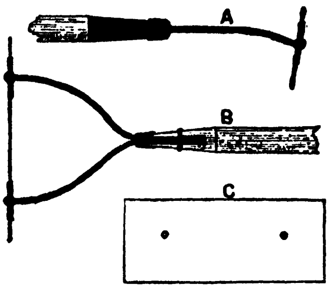

FIG. 110.—Scraper for cleaning droppings boards.

A. Side view of scraper. Note how the lower edge is turned in ½ in. to make it cling to the boards. For scraping next to wall, turn scraper over and use top edge.

B. Top view of scraper showing attachment to rake or hoe handle. The handle is 4 to 5 ft. long and should be strong, rather stiff, but not too heavy. The handle should have a strong iron ferrule to receive forked irons connecting handle to scraper. These irons may be made of 5⁄16 or ⅜ square or round steel to make it strong and stiff. The ends which go into handle may be tapered or reduced in size somewhat and welded. Make sure it is riveted through the ferrule.

C. Blade for scraper 4 by 10 in. The 3⁄16- or ¼-in. holes are 2 in. from ends and the edge of holes is ¼ in. above the middle. (*Ohio Agr. Exp. Sta.*)

The poultry part of the farm organization should be regarded as one of the farm units and should be treated as such. On many farms the cash income obtained from poultry exceeds that obtained from each of several grain crops, several acres being used in the growing of each of these crops. Setting aside a few acres for the poultry plant is thoroughly justified and should prove to be a good investment in increasing the returns from the poultry flock.

The growing stock should be kept separate from the adult stock because of the possibility of transmitting disease from the adult to the young stock and because the land on which the adult stock has been allowed to run for several years is liable to be badly infested with parasites. Chickens and turkeys should be kept separate, for the simple reason that the former may become infected with the "blackhead" organism common to turkeys, and turkeys may become infected with a rather common chicken disease. Also, all chickens should be kept separate from swine, especially in the midwestern sections of the United States where it has been shown that swine sometimes become infected with avian tuberculosis organisms.

The mortality that usually occurs in growing and adult stock may be materially reduced by providing the birds with an alternate yarding system. Probably the best arrangement is to provide each colony brooder and each laying house with three yards which the birds would be allowed to use every 3 or 4 weeks. By alternating the birds in the yards every 3 or 4 weeks each yard is kept reasonably sanitary, especially if the

soil in the immediate vicinity of the house is cultivated and treated with lime, and young green grass is available for the birds throughout the season. The importance of clean range for both young and adult stock

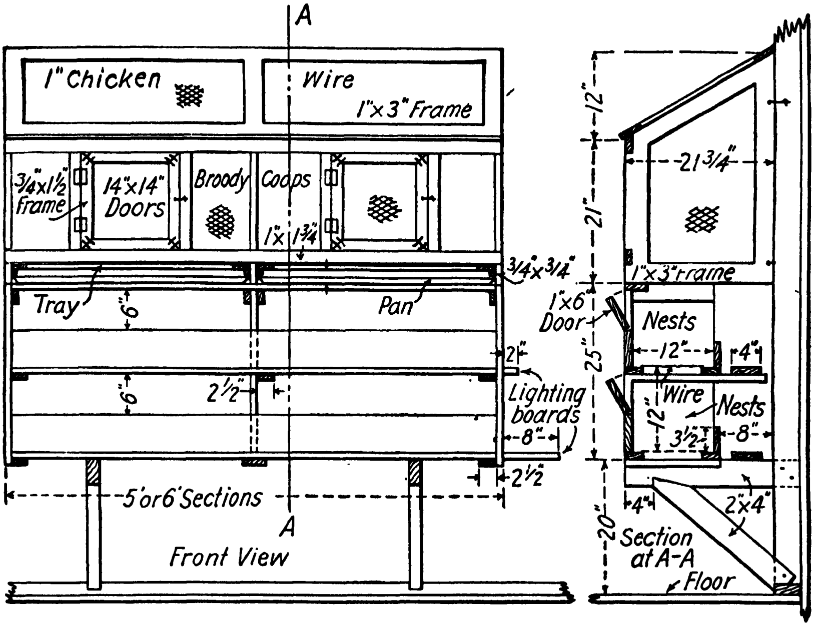

FIG. 111.—Dark nests and broody coop above them. (*Wash. State Agr. Exp. Sta.*)

cannot be emphasized too strongly. For young stock the size of each yard will depend upon the size of the colony of chicks being brooded and reared; each yard should be large enough to provide the chicks with an

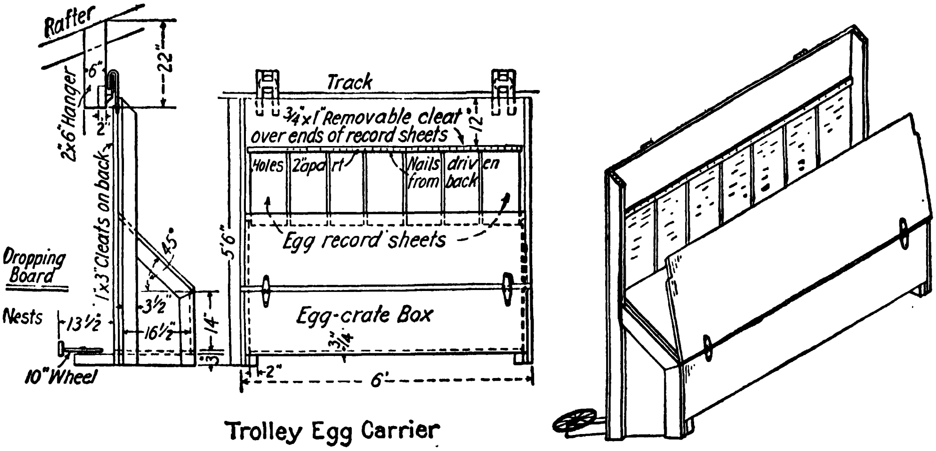

FIG. 112.—Trolley egg carrier. (*Plan by Wash. State Agr. Exp. Sta.*)

adequate supply of young grass while they are in the yard. For adult stock a good grass sward can be maintained on fertile soil, allowing about 200 birds to the acre.

One very important factor often overlooked in connection with the yarding of poultry is the fertilizing value of the poultry manure deposited on the land by the fowls as they graze on the grass. The British Ministry of Agriculture, in a study on the effect on vegetation and soil of poultry on range, has submitted the following as the average analysis of poultry manure:

	Per Cent
Moisture	52.93
Organic matter	29.30
Total nitrogen	2.12
Total potash (K_2O)	0.60
Total phosphoric acid (P_2O_5)	1.21
Total calcium oxide (CaO)	1.16

In experiments conducted in England on raising poultry on grasslands, it was found that there was a general increase in the protein and phosphoric acid content of the grass on which poultry was kept. On the other hand, it was found that on land on which poultry was kept, lime was lost from the soil at an extremely rapid rate. When 200 adult birds were given an acre of acid land for grazing, it was found that about 650 lb. of burnt lime were required. Another outstanding observation made in this experiment was that the available phosphoric acid in the surface soils increased from 0.008 to 0.032 per cent when poultry had used the same land 3 years in succession. It was also noted that the effect of 4 or more years' continuous stocking with poultry on the same land was to cause the ratio of available phosphate to available potash to become abnormally high. This lack of balance was developed most strikingly in the case of chalk soils on which poultry had been kept for over 8 years. Since the phosphate accumulates in the top few inches of soil, the most satisfactory treatment might be to plough up the yard, apply potash, and reseed to grass.

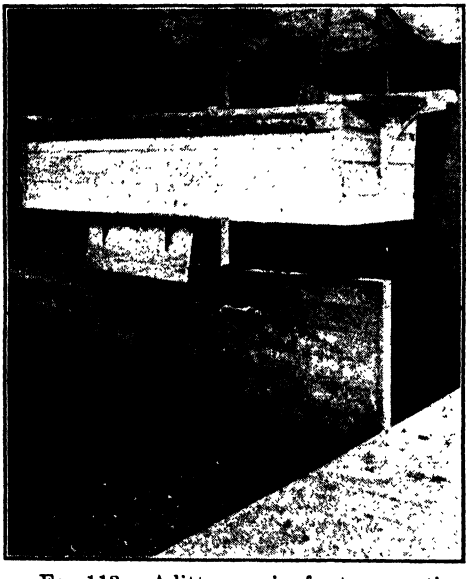

FIG. 113.—A litter carrier for transporting the manure from the droppings boards to the manure house or pit. (*U. S. Dept. Agr.*)

The combined management of poultry and the maintenance of soil fertility presents a problem to the farm poultry raiser. In order to provide suitable range and green feed for poultry, a dense sward of young

green grass must be maintained. The high nutritive value of young green grass is well established, and it behooves the poultryman to do

FIG. 114.—A crate for catching chickens. At each end there is a sliding door that can be raised, and there is a sliding door in the top. (*U. S. Dept. Agr.*)

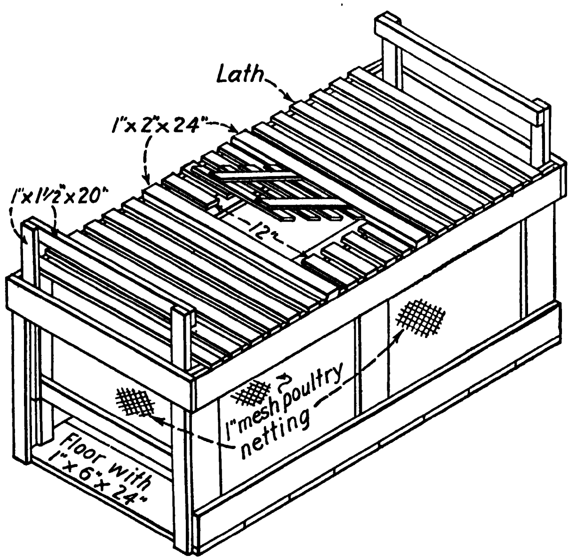

FIG. 115.—Poultry-catching crate, which is placed in front of the runway to the house. (*Plan by Kan. State Ext. Service.*)

everything possible to provide the birds with yarding conditions that will supply succulent grass and at the same time maintain sanitary soil which will promote the health of the birds. Where the triple-yard system of

yarding poultry is employed it would seem desirable to lime the land at the rate of about 1 ton per acre and also add potash at the rate of 300 lb. per acre once in every 4 years in order to maintain a balance with the

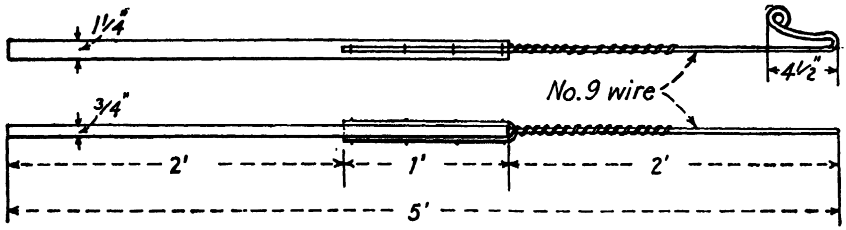

FIG. 116.—Method of constructing a catching hook. (*Calif. Agr. Exp. Sta.*)

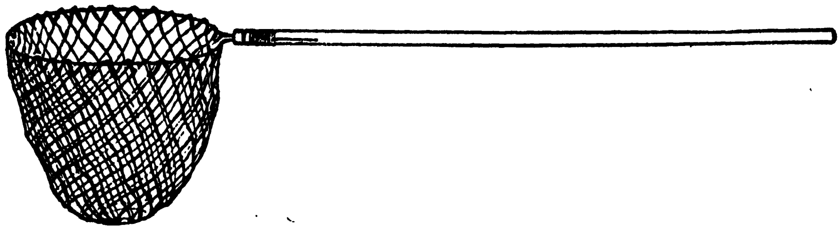

FIG. 117.—Net for catching chickens. (*Calif. Agr. Exp. Sta.*)

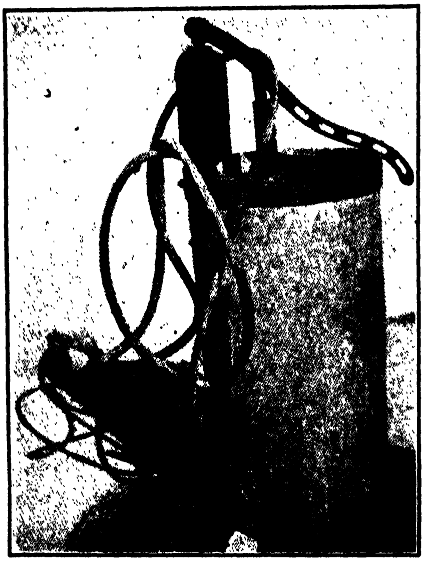

FIG. 118.—A spray pump is very useful for disinfecting poultry houses. (*Ill. State Coll. Agr.*)

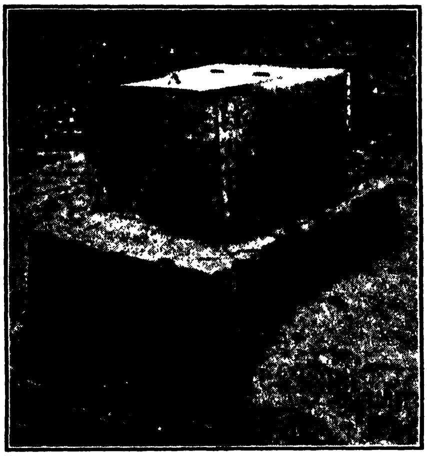

FIG. 119.—A good incinerator for the poultry farm. (*N. J. Agr. Exp. Sta.*)

phosphorus added to the soil by the fowls. The manure deposited by a flock of growing or adult birds would enable a considerable reduction to be effected in the expenditure on nitrogenous fertilizers applied to stimulate the growth of grass.

Certain it is that farmers and commercial poultrymen should give much more thought than is customary not only to the fertilizing value of poultry manure but also to the advantages from the standpoint of controlling mortality by providing an adequate yarding system for their young and adult stock.

KEEPING LAYERS IN CAGES

Partly as the result of high mortality which has occurred in many laying flocks kept in the ordinary type of house and partly because of the high cost of land in certain sections, many poultrymen have adopted the system of keeping layers in cages. The diet of birds thus confined must be much more carefully balanced than in the case of birds that have access to sunlight and a good grass range. Nevertheless, under proper conditions it is possible for some poultrymen to operate a laying-cage system successfully and profitably, provided the overhead costs and maintenance expenses are not excessive.

Houses for Laying Cages.—The proper type of house for laying cages is relatively more expensive than the ordinary type of house, because the ceiling must be higher and the house should be better insulated than is necessary in most of the houses where chickens are kept on the floor. Of course, there are no nests, roosts, or droppings boards to be provided, but these items are in many cases more than offset by the expense of the laying-cage units.

The building should be of a size and shape to accommodate the particular style and number of laying-cage units to be installed, allowing plenty of room for the aisles and at the ends of the cages. A feed room, an egg room, and a storage room should be located convenient to the laying-cage room. The ceiling of the laying-cage room should be about 10 ft. high in order to provide for adequate ventilation. The windows should be placed so that they can be opened if necessary for ventilation purposes and at the same time provide for proper lighting. The walls should be well insulated, care being taken to keep out mice and rats. The floor should be provided with a drain.

Temperature Requirements.—In the southern sections of the United States it is probably not necessary to heat the laying-cage room during the winter months, but in the North some heat is apparently necessary for best results. An even temperature of about 45°F. is desirable, and in the case of a large room containing 1,000 or more layers a hot-air, forced-circulation heating system is preferred by many laying-cage operators.

Ventilation Requirements.—The ventilation of the laying-cage room is a problem requiring a special ventilating system, if large numbers of birds are kept in batteries in a single room. In view of the cubic contents

of most laying-cage rooms in relation to the number of birds involved, however, there is usually no trouble in supplying adequate quantities of fresh air or in removing the carbon dioxide. In order to provide adequate ventilation, electrically operated fans are usually installed in the walls or in ventilating shafts through the roof.

Poultrymen who keep laying hens in cages should appreciate the fact that the ventilation system employed for the battery room should be correct in principle. Accurate knowledge of the size of ventilators required for a particular room is of the greatest importance. In experiments conducted in England it was found that the most satisfactory returns from the birds were obtained when the air was changed eight times per hour. The cowls used on the outlets should operate independently of the direction of the wind.

The cubic contents of the room to be ventilated should be ascertained; multiplying this by 8 gives the amount of air to be introduced into the room and drawn off every hour. The correct type of cowl for the outlet should have a guaranteed rate of extraction per hour, so that the proper number of cowls can be easily determined according to the size of the battery room to be ventilated.

There should also, of course, be a proper balance between intakes and outlets in order to provide for balanced ventilation. The air introduced at the floor level must be entirely draftless. The air movements within a cage room full of laying hens should be tested by an anemometer in order to make sure that adequate ventilation may be provided.

Humidity Requirements.—The health and egg production of the layers is influenced not only by the temperature and ventilation of the laying-cage room but also by the humidity of the air in the room. On the other hand, supplying humidity is not a problem of great concern except in the case of large laying-cage plants, in which case a humidifier attached to the heating unit can be utilized to keep the relative humidity of the air in the room at about 50 per cent.

Building and Installation Service Available.—The building of a proper type of laying-cage room and the proper installation of heating, ventilating, and humidifying units involves so many technical details that a properly qualified engineer should be consulted. A poultryman thinking of installing laying cages for the first time should give most careful consideration to the initial costs of the building and cages as well as to the costs of operating and maintaining the laying-cage system. Particular care should be taken to secure well-made cages which are durable, rustproof, and well finished. The feeding and watering arrangements should be simple, and the system for removing the droppings should be efficient. Probably the best type of cleaning equipment is a heavy galvanized-iron trough over which a metal scraper is drawn.

Laying-cage Management Problems.—Success with laying cages depends not only upon the proper kind of building and efficient cages but also upon the routine care that the birds receive. With certain types of cages two outstanding objections have materially lowered profits. The wastage of feed that occurs, regardless of whether mash or pellets are fed, and the number of eggs that are slightly cracked are factors with which most laying cage operators have had to contend.

The feed and water troughs should be kept scrupulously clean at all times, and the cages should be thoroughly cleaned and disinfected at regular intervals. The droppings should be removed daily, or strong odors are liable to permeate the atmosphere. The method of feeding, including the use of artificial lights, is discussed in subsequent chapters. The ultimate success achieved with laying cages depends largely upon the careful attention to many items of daily management, the details of which are much more exacting than in the case of laying stock kept in the ordinary type of laying house.

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CHAPTER VIII

FEEDING PRINCIPLES

Nowadays it seems a wonder that the chicken could even manage to live, much less grow well and produce eggs at a high rate, prior to the many discoveries of fundamental importance in poultry nutrition. Just as the wild fowl in its original habitat did not have to worry about a balanced diet, so the early poultry raiser was not concerned about the protein, mineral, and vitamin requirements of his birds, which had access to sunshine, grains and seeds, green grass, and insects in variety. Rapid growth in the young stock and high egg production in the laying stock were not essential in the early days of poultry husbandry. Moreover, the grains consumed by poultry in early times were more completely balanced in nutrients than those produced in recent years, many of which are grown on depleted soils.

Then, again, modern milling practices employed in the preparation of various grain foods for human beings have resulted in the development of by-products for poultry having different feed values from those in former times. Various newly developed industries are taking more and more of certain products for food for human beings and for other uses. The processing practices employed in the preparation of feeds used to supplement the grain portion of poultry diets often result in a marked change in the poultry-feeding value of the finished product.

At the same time, it should be noted that while these changes were taking place greater demands were being made for more rapid growth and a higher level of egg production in the poultry raised. Greater productive performance became necessary in order that the production of poultry meat and eggs could be carried on as efficiently as possible. As the feed supply for poultry became more variable, frequently poorer in nutritive value, the needs of the growing and adult poultry became more exacting. This is especially true in the case of growing stock reared and adult birds kept in confinement. It is not surprising, therefore, that successful poultry-feeding practice has become a much more complicated problem than it was even a few years ago.

Largely as the result of raising young stock and keeping adult stock in strict confinement, the field of poultry nutrition has expanded considerably because each new discovery made reveals new fields to be explored. Up to a few years ago the principal concern seems to have been

to make sure that sufficient amounts of protein, minerals, and vitamins were contained in the diet, but recent research has demonstrated that excessive amounts of these nutrients may be either wasteful or even harmful in their effects. The quality as well as the quantity of different nutrients has been shown to be of importance in the preparation of diets for poultry that are raised for egg or meat production. Of particular importance from the standpoint of efficiency of production is the fact that nutritive balance plays a significant role in the over-all usefulness of the diet as a whole. In the field of poultry nutrition comparatively little is known concerning the optimum intakes of the various nutrients, either absolutely or in relation to each other.

The body of the chicken is a chemical laboratory where varied and complex transformations of nutrients are taking place incessantly. The primary purpose involved in the feeding of poultry is to be able to compile diets and employ methods of feeding that will enable the bird to utilize most efficiently the nutrients in the feed for the purpose intended, whether it be rapid growth, good egg production, or fattening.

THE ESSENTIAL NUTRIENTS

The nutrition of poultry involves various chemical and physiological activities which transform the various nutrients contained in feeds into body elements. The chemical composition of the fowl's body when considered in relation to the chemical composition of poultry feeds gives a general picture of the nutrition process. The fowl's body contains the following six distinctly different groups of nutrients: (1) water, (2) proteins, (3) carbohydrates, (4) fat, (5) minerals, (6) vitamins. These nutrients are not evenly distributed throughout the various organs and tissues of the body but are more or less localized according to their functions. Water, of course, is an essential constituent of every organ of the body, though bones, for example, contain relatively less than blood. Proteins are present in every cell and are the principal constituent, except for water, of such organs as the heart and kidney and the muscles, tendons, and egg white. Fat is usually found deposited under the skin, around the intestines and kidneys, but is also present in other parts. The presence of carbohydrates in the fowl's body is not indicated in the accompanying table, although small amounts are present. Minerals are found in varying amounts in different organs and structures; and vitamins, for the most part, are found in the liver and in the egg.

The nutritive value of poultry feeds is determined, for the most part, by the presence or absence of the six different groups of nutrients: water, carbohydrates, fat, protein, minerals, and vitamins.

Water.—Water, which is composed of the elements hydrogen and oxygen in the proportion of 2 to 1 (H_2O), not only accounts for approxi-

TABLE 32.—COMPOSITION OF FOWL AND EGG[1]
(Lippincott, 1927)[2]

	Water, per cent	Protein, per cent	Mineral, per cent	Fat, per cent
Leghorn hen, entire fowl	55.80	21.60	3.80	17.00
Mature Plymouth Rock, capon	41.60	19.40	3.70	33.90
New-laid egg, entire	65.90	12.83	10.68	10.59
New-laid egg, without shell	74.45	12.16	0.97	9.74
White of egg	86.20	12.30	0.20	0.60
Yolk	48.63	17.58	1.55	32.23
Dry matter in hen	.....	48.90	8.60	38.50
Dry matter in entire egg	.....	33.30	35.60	25.90
Dry matter in entire egg aside from shell	.....	49.80	3.50	38.60

[1] The analyses recorded in this table are from several different sources and are not always in exact agreement.
[2] LIPPINCOTT, WILLIAM A., "Poultry Production." By permission of Lea & Febiger, publishers.

mately 56 per cent of the fowl's body and 66 per cent of the egg but ranks far above any other substance as regards rate of turnover in the body. Water facilitates cell reactions and is able to absorb the heat of these reactions with a minimum rise in temperature. The latent heat of vaporization that water possesses enables it to play an important role in regulating body temperature. Water serves an important role in lubricating the joints and acts as a water cushion for the nervous system. It serves to soften the feed, aids in the processes of the digestion and absorption of other nutrients, serves in transporting the end products of digestion from the digestive tract to various parts of the body, and assists in the elimination of waste products.

Carbohydrates.—The carbohydrates, for the most part, do not occur as constituents of the animal body. Nevertheless, they form by far the largest share of the poultry diet for the simple reason that they constitute about three-fourths of the dry weight of plants and cereals. The plant, with the aid of its chlorophyll, utilizes the energy of the sun to build up carbohydrates, such as starches, sugars, and cellulose. The carbohydrates are composed of carbon, hydrogen, and oxygen, the hydrogen and oxygen nearly always being in the same ratio as in water. In the poultry diet the carbohydrates serve as a source of energy for the fowl's body and for the production of fat.

Starch is a common substance in all poultry diets, the starch of the corn kernel being a common source. Sugars are also used in the diet, lactose, the sugar of milk, being a familiar example. Cellulose represents the crude fiber of the poultry diet but is not a good source of energy in poultry nutrition.

Fats.—The fat that is deposited under the skin, around the gizzard and intestines, and elsewhere in the body as well as in the yolk is derived largely from the starches and fats in the feed. Fats comprise two groups of substances, the true fats and certain fatlike substances, such as ergosterol and cholesterol.

The true fats are comprised of carbon, hydrogen, and oxygen but in different proportions from those in the carbohydrates, the proportion of oxygen in fats being much lower than in carbohydrates. Fats serve as sources of energy for the body, just as carbohydrates do, but since fats contain relatively less oxygen they yield approximately 2¼ times as much energy as a similar quantity of carbohydrates.

Cholesterol is a fatlike substance which is constantly being formed and destroyed in the body, occurs in the blood, and probably serves for the transport of fatty acids. Ergosterol occurs in plants and is associated with cholesterol in animals.

Proteins.—Since protein is the principal constituent of the organs, muscles, and other parts of the fowl's body, an adequate supply of protein should be available in the feeds in order that growth and tissue repair may proceed normally. Not only do plant proteins differ from each other, but they also differ from animal proteins. Moreover, each animal contains many proteins peculiar to the species to which the animal belongs. Proteins are complex substances containing the elements carbon, hydrogen, oxygen, and nitrogen; most proteins also contain sulfur, and a few of them contain iron and phosphorus. The outstanding characteristic of proteins is the presence of nitrogen, of which they contain approximately 16 per cent. Therefore, in calculating the amount of protein in any poultry feed the amount of total nitrogen present is multiplied by 6.25, since 100 divided by 16 = 6.25. It should be observed, however, that it is not always true that all of the nitrogen is in protein form, nor do all proteins contain 16 per cent nitrogen.

It has been shown by the results of experiments conducted at St. Thomas' Hospital Medical School, London, England, that proteins differ with respect to their biological value, which is expressed in terms of the percentage of nitrogen retained by a bird for maintenance or productive purposes to nitrogen digested or absorbed. In other words, the biological value of a protein refers to its utilizability. It was found that the biological value of a protein or group of proteins depended partly upon the level at which the protein or group of proteins was fed and partly upon the chemical nature of the other proteins contained in the diet. Equivalent amounts of proteins from the sources indicated on the next page were fed to Light Sussex chicks in order to determine the growth-promoting values of the various proteins, the value of 100 being attributed to the protein of milk, called "caseinogen."

The results given here indicate quite clearly that proteins of animal origin are superior in biological value to proteins of plant origin.[1]

Fresh egg white	130.6	Soybean	55.6
Fresh egg yolk	100.9	Blood meal	48.0
Caseinogen from milk	100.0	Split peas	45.0
Fish meal	85.3	Bean meal	36.3
Dried egg yolk	80.5	Lactalbumin	31.6
Fat-free meat meal	74.1	Alfalfa	25.6
Wheat germ	68.0	Grass	22.0
Dried yeast	62.0	Lentils	19.0

The differences in the biological value of proteins from different sources soon established the fact that the differences were associated with the presence or absence or partial deficiency of certain amino acids, which are the constituents out of which the plant and animal proteins are constructed. Although 23 different amino acids have been identified as occurring in proteins, there are at least 4 that have been found to be essential for promoting growth in poultry. These four essential amino acids are methionine, lysine, histidine, and tryptophane. Certain other amino acids may be essential for specific functions, such as egg production. The reason that some of the others are not necessary in the diet is because they can be built up in the animal body from other amino acids. Since the fowl's body is unable to build up certain amino acids that are present in its proteins, it is obvious that the value of a given protein in the poultry diet is governed by its amino-acid make-up.

Minerals.—Animals can live but a few days on feed that is practically free of mineral matter. The need of minerals in the diet is made clear when the mineral content of the fowl and the egg is taken into consideration, approximately 8.6 per cent of the dry matter of the fowl's body and about 35.6 per cent of the dry matter in eggs being composed of mineral matter. The shell constitutes approximately 10 per cent of the total weight of the egg and is composed almost entirely of calcium carbonate. A large number of mineral elements occur in combination with each other and in combination with the organic constituents of the fowl's body; the bones and eggshell especially are rich in minerals or ash.

Up to the present, the following minerals have been found to perform essential functions in the body: calcium, phosphorus, sodium, magnesium, chlorine, potassium, iron, sulfur, iodine, manganese, copper, and zinc. Other mineral elements, such as barium, strontium, and vanadium, have been found to be more concentrated in the blood of the chicken and in the egg than in the feed, and it may be that these mineral elements are of considerable physiological importance. Calcium, in the form of a carbonate, constitutes most of the eggshell. Calcium, sodium, and potassium salts are essential for muscular activity; and calcium, phosphorus,

and magnesium, in the form of inorganic salts, are important constituents of bone. The egg contains sulfur and phosphorus; and the blood contains iron, copper, and chlorine. Manganese is necessary for proper bone formation, and zinc is necessary for optimum growth. Iodine is contained in extremely small amounts in the body but is necessary in feed for the proper functioning of the thyroid gland.

The distribution of some of the more important minerals in the soft tissues and bones of birds is given in the accompanying table.

TABLE 33.—AMOUNTS OF SOME IMPORTANT MINERALS IN GRAMS IN THE DRY MATTER OF 9-MONTHS-OLD LIGHT SUSSEX COCKEREL AND PULLET
(Halnan, 1936)

Mineral	Cockerel		Pullet	
	Flesh and offal	Bones	Flesh and offal	Bones
Ash	17.64	68.74	14.22	55.89
Total phosphorus	2.848	11.60	2.418	9.88
Phosphorus in ash	2.178	11.52	2.292	9.84
Total sulfur	3.733	0.922	3.160	0.742
Sulfur in ash	0.173	0.205	0.146	0.140
Calcium	0.430	25.68	0.345	20.77
Magnesium	0.478	0.807	0.374	0.624
Potassium	4.778	0.787	3.630	0.566
Sodium	1.443	0.713	1.113	0.595
Chlorine	2.283	0.817	1.996	0.552
Iron	0.131	0.030	0.128	0.034

Aside from providing mineral constituents for the fowl's body, minerals in the diet are of great importance in enabling fowls to utilize other nutrients to best advantage. At the same time, most of the minerals are required in relatively small amounts.

The fact that a given mineral element is essential in the diet is demonstrated by the structural or functional injury occurring in birds given diets abnormally low in that particular element. Fortunately, most of the essential mineral elements are contained in sufficient quantities in the normal diet of the chicken so that little concern need be given regarding supplying additional amounts. Of particular concern in poultry nutrition, however, are the absolute and relative amounts of calcium and phosphorus in the diet, especially in relation to the availability of vitamin D.

Vitamins.—Feeds containing adequate amounts of the right kinds of water, proteins, carbohydrates, fats, and minerals sometimes give very unsatisfactory results in growth, bone formation, and egg production.

Investigational work has demonstrated that in many cases the negative results are due to a lack in the diet of certain substances called "vitamins." Although their presence in the diet is of vital importance, they are required in very small amounts. Since the chemical composition of the vitamins was not known at the time of their discovery, they were each designated by a letter. Of the six vitamins, A, B, C, D, E, and G, that have been recognized for some time, C is not important in poultry nutrition. Vitamin G is now divided into two complexes: (1) riboflavin and (2) the filtrate factor. Recent research work has demonstrated the existence of at least two other vitamins necessary for poultry, and undoubtedly the existence of still others will be demonstrated. One of the newly discovered vitamins has tentatively been called "B_4" and is required to prevent an ailment in chicks analagous to a condition known as "crazy chick disease." The other newly discovered vitamin, tenta-

TABLE 34.—EFFECTS OF VITAMIN DEFICIENCIES
(Norris and Heuser, 1936)

Name of vitamin	Nutritional-deficiency disease caused in poultry by lack of the vitamin	Specific effects
A, antiophthalmic	Nutritional roup (xerophthalmia)	Poor growth, swelling and sticking of eyelids, emaciation, incoordination of gait, high mortality
B, antineuritic	Polyneuritis (beriberi)	Poor growth, loss of appetite, spastic head retractions, high mortality
C, antiscorbutic	None	None
D, antirachitic	Rickets	Poor growth, egg production, and hatchability; weak eggshells; lameness; soft bones, swollen rib ends and legbone joints in chicks; brittle bones in mature birds; increased mortality
E, antisterility	None	Failure of hatchability, sterility in males
G, complex:		
1. Riboflavin, growth-promoting factor	None	Failure of hatchability, poor growth, increased mortality
2. Filtrate factor, antipellagric factor	Pellagra (dermatitis)	Incrustations at corners of eyelids and mouth and on bottoms of feet of chicks, rough underdeveloped feathering, growth failure, high mortality

tively called "K," or "antihemorrhagic" vitamin, is required to prevent a condition characterized chiefly by hemorrhages under the skin and in the muscles of chickens.

The egg contains vitamins A, B, D, and G; and the liver contains vitamin G. The principal value of vitamins lies largely in their ability to promote the physiological well being of the chicken and, with respect to some of them, provide for proper growth and bone formation and to maintain egg production and hatchability. The table on page 247 gives the name associated with each vitamin, the name of the nutritional-deficiency disease resulting from a lack of the vitamin in the diet, and the specific effects of the vitamin deficiency.

VARIABLE QUANTITIES OF NUTRIENTS IN FEEDS

Although the different cereal grains and their by-products are fairly constant with respect to the relative proportions of the different nutrients they contain, the student of poultry nutrition should realize, nevertheless, that variations do occur even in the same variety of the same species. The kind of soil and conditions under which the plants are grown have an influence on the chemical composition of the green plant, the mature plant, and the seeds produced. Different samples of the same variety of wheat have been shown to vary in their protein content as well as in the content of other nutrients. The same is true of other cereals. Wheat bran and wheat middlings each also differ in their chemical composition depending upon the different parts of the country in which the wheat was grown. Also, the milling processes involved in the milling of such feeds as wheat bran and wheat middlings sometimes have an important bearing on the relative proportions of the different nutrients in the finished product.

The kind of materials used in the preparation of and the method of processing meat scraps determines not only the relative amount but also the feeding value of the proteins contained therein. As a matter of fact, two different samples of the same brand of meat scraps may be very similar in composition as determined by chemical analysis but differ considerably in feeding value, largely because of differences in amino-acid content. Fish meals likewise differ in the relative proportion of the protein and other nutrients they contain depending upon the kinds and parts of fish used and the process employed in manufacturing the meal, vacuum-dried products usually being superior to flame-dried products from the standpoint of their feeding value. The proteins of milk are very sensitive to the intensities and duration of heat treatment employed in the manufacture of dried-milk products. Excessively high temperatures tend to destroy some of the amino acids, certain of which are regarded as essential in poultry nutrition. The California Agricultural Experiment

Station has shown that by subjecting numerous animal-protein concentrates to a special form of chemical analysis it was possible to establish protein-quality indexes for the protein concentrates which served as an indication of their nutritive value for chicks. It was found that a low percentage of copper-precipitable nitrogen in a protein concentrate is an excellent criterion of low nutritive value.

Two samples of the same variety of a cereal may differ in their mineral content. Blue grass may differ quite considerably in the percentage of calcium and other minerals depending upon the kind of soil on which it was grown as well as the stage of growth at which it was cut for feeding purposes. Other illustrations of the variability in the mineral content of a feed could also be given, but it is sufficient to observe that the mineral content of any feed is determined by such factors as the kind and amount of fertilizers applied to the soil on which the feed was grown, the effective rainfall, and other weather elements. Soils that are relatively low in calcium or in phosphorus produce crops that are relatively low in these nutrients.

The vitamin content of a feed is a variable factor, sometimes markedly so. The amount of vitamin A in yellow corn is somewhat variable depending upon the genetic constitution of the corn. Cod-liver oils sometimes differ a great deal in the potency of vitamins A and D. Moreover, the vitamin A potency of a feed mixture to which cod-liver oil has been added varies depending upon the extent to which oxidation of vitamin A has taken place from the time the cod-liver oil was added to the feed mixture to the time the feed mixture is fed to the birds.

From these few illustrations of the variable quantities of nutrients in feeds, it is obvious that the chemical composition of a feed is not an accurate index of the nutritive value of the feed. Feeding tests are necessary to determine the nutritive value of a feed or a mixture of feeds. A complete determination of the nutritive value of a feed or a mixture of feeds must take into consideration (1) the total nutrient content of the feed or mixture of feeds, (2) the loss or wastage of the various nutrients that occurs in the process of digestion, and (3) the loss or wastage of various nutrients that occurs in the process of their conversion into tissue constituents of the body or the constituents of body secretions.

THE DIGESTION OF NUTRIENTS

Since most of the nutrients in feeds are not absorbed by the fowl's body in the form in which they occur in seeds, it is obvious that these nutrients must be "broken down" before they can be converted into the nutrients found in body tissues and secretions of the body. The process of digestion includes all of the changes that take place in the feed from the time it is consumed until the nutrients in the feed are in proper form

and condition to be absorbed by the blood for assimilation by the tissues of the body.

Feed Passage through Digestive System.—The digestive system of the chicken has been described in Chap. II (The Biology of the Chicken), so that at this time it is necessary only to trace the various steps that feeds take in their passage through the digestive system. Feed picked up is swallowed with the assistance of the tongue and is forced through the digestive tract by means of muscles in the walls of the tract. If the bird has had no feed for several hours, the first few mouthfuls swallowed pass directly into the empty gizzard, reaching that organ in about 15 to 30 sec. after being picked up. In the case of birds that have been feeding regularly, however, a fresh mouthful of feed when swallowed passes down the gullet and into the crop, which continues to receive feed as long as the gizzard is full or partially full. As the feed passes from the crop to the gizzard, it usually pauses in the proventriculus for a period of approximately 7 sec. Small quantities of feed take relatively a longer time to leave the crop than larger quantities.

Upon reaching the gizzard the feed is ground into a fine mass by the rhythmic contractions and relaxations of the gizzard, the pressure in grinding being very great. After the gizzard has ground the feed completely, it passes into the small intestine, where it is thoroughly mixed and brought into intimate contact with the intestinal wall.

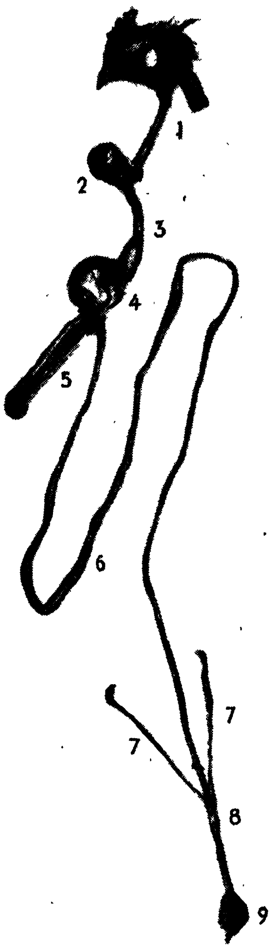
The feed mass passes from the small into the large intestine at the juncture of which the caeca, two blind pouches about 5 in. in length, open into the intestinal tract. The caeca rhythmically expand and contract and thus receive and reject the fluid contents of the intestine. The fluidlike feed mass passes along the large intestine until it accumulates at the cloaca, where portions are expelled at intervals.

From the time that feed is picked up by the laying bird approximately 2½ hr. are required for the feed mass to reach the cloaca. The rate of the passage of feed through the digestive tract of the adult hen not in laying condition is considerably slower than in the hen in laying condition, being about 8 hr. In the case of the broody hen the rate of passage is about 12 hr.

The Process of Digestion.—During the process of digestion the carbohydrates, fats, and proteins are "broken up" into fine particles by the secretions of various glands that are present in different parts of the digestive system. These glands secrete ferments or enzymes, which have the remarkable ability of bringing about changes in other organic compounds without themselves' being changed. Their function is to attack the nutrients contained in the feed in order that they may be converted into nutrients which can be taken up by the innumerable small projections, called "villi," that line the intestinal tract and thus be

absorbed by the blood stream which connects with the villi. In other words, the starches and sugars comprising the carbohydrates, the fats, and the proteins are "broken up" into simpler compounds which can be absorbed by the body.

The mouth contains many salivary glands which secrete a starch-splitting enzyme called "ptyalin," converting starch in the feed into an



1. *Gullet.*
   Ptyalin in salivary secretions converts starch into maltose.
2. *Crop.*
   Lactase converts lactose into glucose and galactose.
3. *Proventriculus.*
   Pepsin in gastric juice converts proteins into proteoses and peptones.
4. *Gizzard.*
5. *Pancreas*, between folds of duodenum.
   Amylopsin in pancreatic juice converts starch into maltose.
   Pancreatic lipase in pancreatic juice converts fats into glycerols and fatty acids.
   Trypsin in pancreatic juice converts proteins into proteoses, the latter into peptones and polypeptids, both of which are converted into amino-acids.
6. *Small Intestine.*
   Maltase in intestinal juice converts maltose into glucose.
   Sucrase in intestinal juice converts sucrose into glucose and fructose.
   Erepsin in intestinal juice converts peptones into amino-acids.
7. *Caeca.*
8. *Large Intestine.*
9. *Cloaca.*

FIG. 120.—Showing the regions of the digestive tract in which various digestive processes take place. (*Photograph by Winter.*)

end product called "maltose." There are no glands in the crop, which serves largely as a storage sac, but it is in the crop that the ptyalin acts as well as certain enzymes contained in the feed, where it takes on an acid reaction due to the presence of lactic acid. While the feed is in the proventriculus it is mixed with gastric juice containing hydrochloric acid and an enzyme called "pepsin," which reduces the protein in the feed into peptones. The hydrochloric acid contained in the gastric juice secreted

by the glands of the proventriculus acts as a solvent on mineral matter, making its final absorption possible.

The gizzard does not contain any glands that secrete enzymes, but it is worth noting that the gastric juice is incapable of digesting the cellulose walls of the various grains until they are ground up by the gizzard. The gizzard acts as a filter so that no feed passes out until it is finely ground.

The liver secretes bile, which reaches the distal portion of the duodenum by means of two bile ducts, the one from the right lobe of the liver being enlarged to form the gall bladder. The bile emulsifies and dissolves the fats in feed so that enzymes can act on the fats more readily. The bile contains salts which help to neutralize the acid of the gastric juice, thus preparing the feed for further action by the juices secreted by the pancreas. The liver also serves in the synthesis of the uric acid that escapes in the urine.

The pancreas, which lies between the U-shaped loop of the duodenum, secretes pancreatic juice, which gains access to the duodenum by means of three ducts. The pancreatic juice is weakly alkaline in character and contains the enzymes amylopsin, which converts starch into maltose; trypsin, which converts any previously undigested proteins into proteoses, the latter into peptones and polypeptids, both of which are converted into amino-acids; and lipase, which converts fats into glycerol and fatty acids. The glycerol and fatty acids are absorbed by the villi of the intestinal tract and upon being reformed into fats pass by way of the lymphatic system into the blood stream.

Distributed throughout the small intestine are "Lieberkuhn's glands," which secrete the intestinal juice containing the enzyme erepsin, which converts peptones into amino acids. The intestinal juice also contains the enzyme maltase, which converts maltose into glucose; and the enzyme sucrase, which converts sucrose into glucose and fructose. Aside from its digestive function, the small intestine also acts as an organ of absorption by absorbing soluble nutrients and inorganic salts.

The caeca aid in the digestion of the fiber contained in feed.

The large intestine serves in the absorption of water from the urine as it is delivered by the ureters from the kidney. The urine is expelled with the feces in the form of a white paste.

The various mineral nutrients in the feed are usually absorbed from the intestine without undergoing any change in composition. In so far as known, the vitamins are also absorbed directly by the body without undergoing any change.

Wastage of Nutrients in Digestion.—It is a significant fact that the nutrients absorbed by the fowl's body to enable it to perform its normal functions and in the formation of new tissues and secretions are invariably

smaller in amount than the nutrients that must be supplied in the feed for these purposes. Rarely is any nutrient contained in the feed completely digested, much less completely utilized. Moreover, the level of feeding affects the wastage of nutrients in digestion, for when the chicken is fed excessive amounts of feed the nutrients are digested less thoroughly than when the chicken is fed a scanty diet. Then, again, nutrients that are not properly balanced in the diet apparently are not digested so well as when they are properly balanced. An excessive supply of any particular nutrient constitutes a wastage in feeding practice because a higher proportion of the nutrient remains undigested than when the optimum amount is fed. In fact, the optimum amounts and proportions of some of the various essential nutrients in the feeding of poultry for any particular purpose have as yet to be determined.

THE METABOLISM OF NUTRIENTS

The metabolism of the nutrients involves the various processes they undergo from the time they enter the blood stream, for which they were prepared by the processes of digestion, until the waste products are finally excreted from the body.

Upon entering the blood stream, the nutrients, such as the amino acids and glucose, are carried to different parts of the body for tissue building, the development of secretions, and the production of energy. The circulatory system, therefore, serves a very important function in metabolism. The blood is continually in circulation and is composed largely of two kinds of cells, erythrocytes and leukocytes. The erythrocytes, or red blood cells, contain a protein substance called hemoglobin, which serves as a vehicle for carrying oxygen to different parts of the body.

The respiratory system also serves an important purpose in metabolism, inasmuch as the oxygen breathed in and transported to different parts of the body by the hemoglobin is absolutely essential in order that the various nutrients in feeds may be "broken up" by a process known as "oxidation." The oxidation products are water, carbon dioxide, and other gases; and the heat given off in the process is known as the "heat of combustion." The carbon dioxide is exhaled by the bird in breathing.

Recent research work has demonstrated that the secretions of the regulatory system, comprising the endocrine glands, sometimes have a very marked effect on metabolism. The endocrine glands are ductless glands, such as the thyroids, pituitary, pancreas, ovary, and testes, which secrete products known as "hormones" which are thrown into the blood stream and are carried to various parts of the body. Comparatively little is known concerning the influence of the various hormones on metabolism, although it has been demonstrated that several hormones have a pro-

nounced effect in regulating various functions of the body. Some evidence has been secured showing that certain hormones tend to raise the level of metabolism of certain nutrients, whereas others, when secreted in excessive amounts, have a depressing effect on the metabolism of certain nutrients. Some hormones serve the purpose of maintaining a proper balance of nutrients in the blood stream.

Hydrogen-ion Concentration.—Most of the reactions that occur in the body take place in water solutions, the acidity or alkalinity of these solutions being due to hydrogen or hydroxyl ions. The concentration of hydrogen ions times the concentration of hydroxyl ions equals a certain constant, and if the concentration of either ion is increased the concentration of the other ion must diminish correspondingly. The measurement of the concentration of one ion indicates the degree of acidity or alkalinity of the solution, the term "hydrogen-ion concentration" being used to designate the degree of concentration. The hydrogen-ion concentration is expressed in terms of the hydrogen-ion exponent, or pH value. A pH value of 7 for a solution indicates neutrality, a pH value above 7 indicates an alkaline solution, and a pH value below 7 indicates an acid solution. It is very important to keep in mind that a solution having a pH value of 6 has ten times as many hydrogen ions as a solution having a pH value of 7 and that a solution having a pH value of 5 has one hundred times as many hydrogen ions as a solution having a pH value of 7. Moreover, the difference between pH 4.0 and pH 4.1 is many times as great as the difference between pH 4.9 and pH 5.0.

From work done at the Nebraska and Oklahoma Agricultural Experiment Stations and other institutions it is possible to give the following brief statement of the pH values of the contents of the digestive tract: The contents of the crop are acid; the contents of the proventriculus are more acid than those of the crop; the contents of the gizzard are more acid than those of the proventriculus; the contents of the duodenum and upper portion of the small intestine are less acid than the contents of the crop; the contents of the lower portion of the small intestine, caeca, and large intestine are approximately neutral.

The fowl's digestive tract is well adapted to take care of all normal changes in the feed and water ingested. According to the Oklahoma station the pH of the digestive tract is apparently not involved in any changes in the metabolism of varying amounts of protein and fiber. It was also observed that changes in the calcium-phosphorus ratio produced no changes in the pH values and that large amounts of basic salts decreased the acidity of the crop, proventriculus, and gizzard only slightly. On the other hand, work done under the auspices of the Ohio University and College of Veterinary Medicine showed that the pH of the contents of the duodenum and large intestine was increased and the pH of the

contents of the caeca was markedly decreased by feeding diets containing 20 per cent or more of milk products.

Carbohydrate Metabolism.—The carbohydrate of the blood stream is in the form of glucose, as observed previously. Upon being oxidized, the primary function that glucose serves is as a source of fuel. Should there be a surplus of glucose in excess of fuel needs, it is used for the formation of a substance called "glycogen," which is stored principally in the liver to be oxidized for heat and energy.

Glucose in the blood stream may also be used in the formation of body fat and egg fat, the body fat being oxidized for heat and energy. A very small portion of the glucose in the blood stream is used in the formation of the carbohydrates of the body cells. Regardless of the proportion of

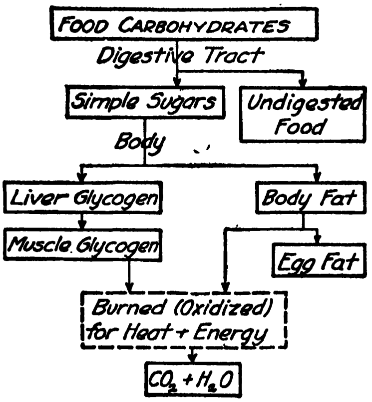


FIG. 121.—Scheme illustrating the use of carbohydrates in the body. (*After Holst and Newlon*, 1927.)

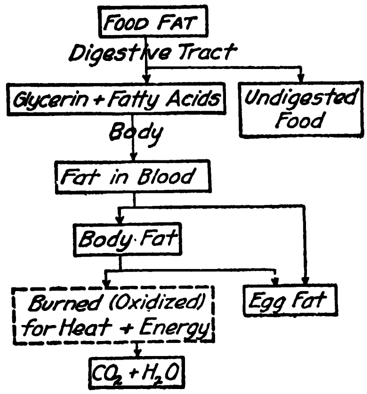


FIG. 122.—Scheme illustrating the use of fats in the body. (*After Holst and Newlon*, 1927.)

carbohydrate nutrients contained in the diet, the percentage of glucose in the blood stream is nearly always constant, this being accomplished by hormones secreted by certain endocrine glands.

Fat Metabolism.—As previously pointed out, by far the most of the digested fats pass by way of the lymphatic system into the blood stream, the blood cells changing the neutral fats into what are called "phosphorized fats," which may be used as a source of energy or for storage or for the formation of what are known as "lipoids" of the cells and "sebaceous lipoids" of the skin.

Protein Metabolism.—The different amino acids obtained by digestion from the proteins of the feed are carried by the blood stream to different parts of the body and serve in the formation of the amino acids in the tissues, organs, and other parts of the body. An excess supply of proteins may be used as a source of energy.

The nitrogen utilized is determined by the difference between the nitrogen absorbed from the digestive tract and the nitrogen in the urine.

The nitrogen that is utilized when expressed as a percentage of that which is absorbed gives what is known as the biological value of the protein in question. The biological values of a number of proteins have been given in the fore part of this chapter.

Mineral Metabolism.—Comparatively little is known concerning the metabolism of the different mineral nutrients, although it has been shown definitely that the utilization of mineral nutrients is modified by many factors. For instance, the proper assimilation of calcium and phosphorus in the growing chick is dependent upon an adequate supply of vitamin D. The concentrations of calcium and phosphorus in the diet determine the ratio of these nutrients that permits maximum bone calcification.

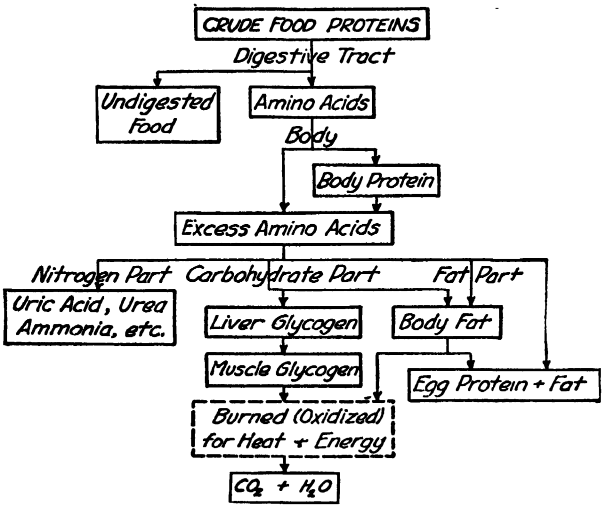


FIG. 123.—Scheme illustrating the use of proteins in the body. (*After Holst and Newlon* 1927.)

The most efficient utilization of minerals is sometimes determined by their relationship in some body function. For instance, the hemoglobin of blood with its incorporated iron is produced only in the presence of copper. It is apparent, therefore, that the utilization of iron is dependent on the presence of copper.

The Wastage in Metabolism.—Not only is there a wastage of nutrients in digestion, as pointed out previously, but there is also a certain amount of wastage in metabolism, since not all of the digested nutrients are utilized. The wastage in metabolism results largely from losses in energy and losses in nitrogen.

The metabolism of the nutrients in the fowl's body involves the production of heat, the greater the feed consumption the greater being the heating effect. In order that the animal may maintain its normal temperature, heat production must be equivalent to heat elimination. As a

matter of fact, heat production is to be regarded as a defense mechanism by which any excessive concentrations of nutrients are removed. Moreover, the more nearly balanced the diet the smaller the proportion of it that is dissipated as heat and the greater, therefore, is the net-energy value of the diet.

The percentage of total protein in the diet has a definite effect on heat losses, the higher the protein content the greater being the amount of heat produced. Protein that is used entirely for the development of new tissue has a smaller heating effect than when it is converted entirely into energy, some of it being lost as heat. Heat that is lost means a loss of energy. The ingestion of protein results in a greater increase in heat production than the ingestion of carbohydrates and fats, the primary cause of this variation in heat production being due to variations in what is known as the "specific dynamic effect," which is defined as the heat increment of a specific kind of nutrient.

The losses in nitrogen during the process of metabolism is measured by determining the amount of feed nitrogen excreted in the urine. One source of nitrogen loss is the continual breakdown in nitrogenous tissues in the body, and a second source is from the incomplete utilization of dietary protein.

THE NET NUTRITIVE VALUE OF FEEDS

The net nutritive value of feeds is determined by the extent to which the nutrients are digested and by the extent to which the digested portions are utilized in the body. It is not so much what the diet *contains* as what it *accomplishes* in the body that counts. Nutrients are rarely completely digested, and frequently the digested portion of nutrients is not completely utilized. There are many factors that affect both the digestibility and the utilizability of a diet.

Coefficients of Digestion.—During recent years the digestibility of a number of individual poultry feeds has been determined by investigators in England and in the United States. The digestibility of a feed is expressed in terms of the digestion coefficient, which refers to the percentage of the nutrient consumed that does not appear in the feces. In order to determine the digestion coefficient of a given feed, the exact chemical composition of the feed is first determined; then definite amounts are fed; and the feces excreted during the experimental period are collected, weighed, and analyzed, the urine from the kidneys having been diverted by an artificial anus, or proper calculations made if the urine has not been kept separate.

The excretion of the urine with the fecal matter is a problem that has made digestion trials with poultry so difficult to carry out as compared with mammals, in which the urine is stored in the bladder and voided

separately from the fecal matter. In digestion trials with poultry, the undigested portion of the nutrients excreted in the feces in relation to the amount of nutrients in the feed gives the digestion coefficient in terms of a percentage.

The digestion coefficients of individual feeds appear to be of rather limited value, however, for several reasons. In the first place, the digestibility of a mixture of feeds does not necessarily represent the *average* of the coefficients of digestion of the separate feeds. When several feeds are mixed together in the diet there is a supplementary or associative effect on the digestibility of the nutrients in the mixture. In the second place, the mechanical condition of the feed, including the degree of bulkiness, apparently affects to some extent the digestibility of some of the nutrients in the mixture. Then, again, it has been demonstrated that certain nutrients, such as some of the minerals and vitamins contained in the mixture, affect the extent to which certain other nutrients are digested. The rate of passage of the feed through the digestive tract, which is conditioned by the method of feeding and by such circumstances as to whether the hen is in a laying, nonlaying, or broody condition, undoubtedly has a bearing on the digestibility of a feed or a feed mixture. The age and the sex of birds may have a bearing on the digestibility of nutrients, thus adding to the difficulties of adopting coefficients of digestion of individual feeds or mixtures of feeds as a guide in poultry-feeding practice.

Net Nutritive Value of Feeds.—In order to determine the actual useful portion of the diet that chickens are fed, the losses occurring in the feces, urine, combustible gases, and heat production must be deducted. The determination of the digestibility of the nutrients is only one step in determining the net nutritive value of feeds. Moreover, the digestible nutrients must not be considered as the final measure of usable energy or the net nutritive value of the nutrients because they are subject to several losses during the course of metabolism.

The net-energy values of individual feeds and nutrients cannot be added together to give the net-energy value of a mixture of feeds making up the diet, for the simple reason that it depends on the extent to which the heat increments of the feed and nutrients are modified by the mixture. Not only is the net-energy value of a feed or nutrient subject to variation, depending upon the kind of a mixture in which it is contained, but the digestibility and metabolizable energy also vary at times.

A deficiency of one nutrient may and frequently does impair the efficiency of all other nutrients. Net-energy values are of greatest value when they are determined for the diet that is as completely balanced as possible for the purpose for which the diet is fed. From a practical standpoint this is largely out of the question because of the number of

determinations involved and because many of the factors that give rise to variations in the determination of digestion coefficients also give rise to variations in the determination of net-energy values.

Nutrient Requirements for Specific Purposes.—The nutrients that are absorbed by the body system in the process of metabolism serve several different purposes, among the more important of which are:

1. To supply the energy required for performing bodily functions and for maintaining a uniform body temperature.
2. To form new cell tissue and body fluids to replace those used up in the bird's daily activities.
3. To form new cell tissue and body fluids required for growth.
4. To supply materials from which sperm and eggs, for market and hatching purposes, are manufactured.

Several nutrients may be required for a specific purpose, or one nutrient may serve several purposes. The nutrient requirements for the different purposes enumerated above may be most logically considered from the following standpoints:

1. Maintenance.
2. Growth.
3. Fattening.
4. Market egg production.
5. Hatching egg production.

The quantitative requirements of the different nutrients naturally increase as the chicken grows, and they vary in proportion depending upon whether chickens are being fattened or fed for market-egg or hatching-egg production.

NUTRITIVE REQUIREMENTS FOR MAINTENANCE

Whether a chicken is being fed for growth, fattening, or egg production, some of the feed given is used for the body processes which must go on in order to support life and maintain the body as a "going concern." In order to continue the chicken's existence, aside from growing, adding tissue, or producing eggs, at least four requirements must be met: (1) the maintenance of normal body temperature, (2) a supply of energy necessary for muscular activity, (3) nutrients for the renewal of tissue, (4) the elaboration of secretions. The demand for feed to meet these requirements is referred to as the "maintenance requirements." A knowledge of maintenance requirements is necessary in order to understand the principles underlying poultry nutrition.

The various bodily processes, such as digestion and metabolism, are best carried on when the normal body temperature of approximately 107°F. is maintained. The energy requirement for maintenance is the minimum amount needed to prevent the loss of any energy from the

tissues. The tissues of the body are continually losing nitrogen and minerals, and these and other losses must be replaced in order to renew the worn-out tissue. The various secretions of the body, such as mucus, enzymes, and hormones, must be maintained at a certain level in order to keep the body in proper functioning condition. At the National Agriculture Research Center it was found that the gross maintenance requirements of 16-month-old White Leghorns averaging about 3.5 lb. each was 64 g., or about 2.25 oz. of feed per bird per day in July.

Energy Requirements for Maintenance.—The minimum energy expenditure of an individual is known as the "basal heat production" and results in a continuous demand for energy. Observations made at the Missouri Agricultural Experiment Station indicate that the basal heat production of chicks in terms of calories per kilo per day is at a maximum at 2 weeks of age with 230 cal. per day, declining thereafter to about 50 to 60 cal. at 8 months. On the basis of heat production per square meter of surface area the maximum of 1,100 cal. is reached at 35 days, after which there is a decline to about 800 to 900 cal. at about 4 months. The Illinois Agricultural Experiment Station has shown that the basal heat production of hens is about 800 cal. per square meter per day, and that of cockerels about 850 cal. Capons have a decidedly lower heat production per unit area.

Whenever the environmental temperature falls below the critical temperature of the chick or adult bird there is a rapid increase in the metabolic rate, and the extra heat required to maintain normal body temperature must be supplied by extra feed in order to avoid the loss of energy. Work done at the National Agriculture Research Center established the fact that the critical temperature of the chick at hatching time is 96°F. It was also shown that 7° increase or decrease from the critical temperature caused about 15 per cent increase in metabolism, and at 70°F. the energy output was twice as great as at 96°F. At the Illinois Agricultural Experiment Station the critical temperature of the adult hen was found to be 62°F. It should be observed, however, that the critical temperature is not a constant factor but is influenced by such things as the amount of feed consumed and the activity of the bird. The higher the level of feed consumption the greater the heat production. For birds in a normally active state the energy requirements are approximately 50 per cent greater than the energy requirements for basal heat production.

Protein Requirements for Maintenance.—Very little work seems to have been done to determine the protein requirements for maintenance in poultry. The need of protein, or other source of available nitrogen, for maintenance appears to be related to the need of replacing the essential nitrogenous constituents of the body which are continually being lost. This breakdown, or catabolism, is referred to as "endogenous" catabolism

and does not seem to be affected by the ordinary environmental factors or by the bodily activities.

The endogenous nitrogen can be used as a measure for the body nitrogen which must be spared from the feed protein for protein maintenance, provided certain assumptions are made as to the losses in metabolism. On this basis, as the result of work done at the Illinois Agricultural Experiment Station, it has been concluded that an endogenous nitrogen value of 0.030 g. per kilogram body weight applies to all species. Since a normal diet should have a biological value of at least 50 per cent in meeting this endogenous loss, the maintenance requirement of digestible nitrogen per kilogram amounts to 0.06 g., or approximately 0.03 oz. per pound live weight.

The results of various lines of work show, however, that the quality of the protein intake has an influence on the amount required for the attainment of complete nitrogen equilibrium. Part of the maintenance requirement is for relatively simple body constituents which can be supplied by incomplete proteins, but complete maintenance involves also the synthesis of proteins needed for the secretion of hormones and digestive juices, so that dietary protein containing all of the essential amino acids is demanded. It follows, therefore, that the quality of protein intake is important in maintenance.

Mineral Requirements for Maintenance.—Many of the mineral elements undergo a very active metabolism in connection with the various processes that are necessary for the normal body functions to proceed in maintenance. The mineral elements are not necessarily used up and excreted in the process, however, as in the case of energy and protein metabolism. On the other hand, there is always some loss of minerals during maintenance, the amount excreted and the amount required for maintenance depending upon a variety of factors, including the nature of the mineral relations in the diet. Only a few of the numerous minerals essential for normal body functions are ever likely to be sufficiently lacking in normal diets to merit attention as regards their requirements in maintenance.

Vitamin Requirements for Maintenance.—Practically no work on the vitamin requirements for maintenance has been carried on except at the Texas Agricultural Experiment Station, the results secured indicating that for White Leghorn pullets, averaging about 3.2 lb. each, 105 Sherman-Munsell units of vitamin A per day, or about 33 units per day per pound live weight, are required.

NUTRITIVE REQUIREMENTS FOR GROWTH

As compared with most other domestic animals, the chicken grows more rapidly, on a good diet doubling its weight in about 2 weeks and increasing it by ten times in about 6 weeks. The rate of growth is deter-

mined by the inherent capacity for growth, the kind and amount of feed consumed, and the environmental conditions under which the chicken is kept.

The Nature of Growth.—Growth is a very complex process involving much more than increase in size, for in the growth of the body as a whole

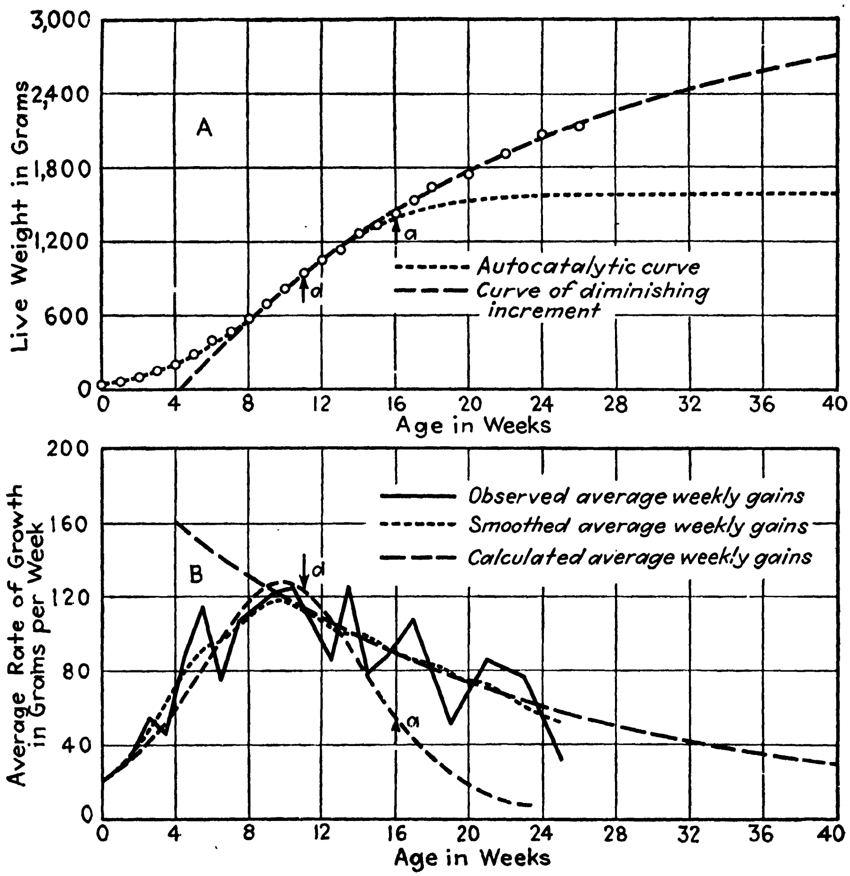


FIG. 124.—Data on growth in Rhode Island Red pullets plotted to show growth curve in *A* and rate of growth in *B*. In each case *a* marks the end of the age interval to which the autocatalytic curve was fitted and *d* marks the beginning of the interval to which the curve of diminishing increment was fitted. (*Titus and Jull*, 1928.)

there must also be a completely coordinated growth of all of its parts. For each species there is a characteristic rate of growth and a characteristic adult size, and, in a general sense, these two statements apply to the various breeds of chicken. Maximum size seems to be determined by heredity, but since nutrition is an essential factor affecting rate of growth and the attainment of maximum size, it is obvious that the most satisfactory diet is one that enables the chicken to take full advantage of its heredity.

Increase in body size involves an increase in the organs and structural tissues such as bone and muscle, this true growth being distinguished from the increase that results from the deposition of fat in the reserve tissue. True growth implies, therefore, an increase in water, protein, and mineral matter and involves an adequate supply of energy-producing nutrients to support the various growth processes and vitamins of various kinds which are essential for the attainment of physiological well-being and the most efficient utilization of feed.

The Growth Curve.—When a baby chick is fed a so-called "normal" diet, growth proceeds as a more or less continuous change until maturity is attained. Although the chicken increases steadily in weight, the percentage increase in body weight from week to week throughout the growing period is not the same. In most cases body weight is approximately doubled each 2-week period up to the end of 6 weeks, but after that the percentage gain in weight is lower.

From studies conducted at the Missouri Agricultural Experiment Station it has been shown that the growth curve is divided into two principal segments, one of increasing and the other of decreasing slope. The point of inflection of the curve depends upon the kind of diet and the amount of feed consumed as well as upon other factors but usually occurs between the tenth and the sixteenth weeks.

From the results secured with Rhode Island Reds at the National Agricultural Research Center it was found that cockerels and pullets attained mature body weight at approximately the same age, but that capons attained mature body weight somewhat younger. The capons grew at about the same rate as the cockerels but showed a greater tendency to fatten.

Growth in Relation to Feed Consumption.—There is a well-defined relationship between the rate of growth and the amount of feed consumed during any given period. In other words, the amount of feed consumed rather than the age of the chicken determines to a large extent the rate of growth.

From the standpoint of the utilization of feed, it has been shown by work done at the National Agricultural Research Center that for each successive 1000 g. of feed consumed by growing chickens there was a relatively smaller increase in live weight. In other words, as the chickens increase in size proportionately more of the feed is used for the maintenance of the body and proportionately less of the feed is used for growth. The utilization of feed for live-weight increase follows the law of diminishing increment. It was also found that the degree of utilization of that fraction of the feed consumed which is utilized for growth, after the other requirements of the body have been satisfied, appears to be independent of the level of nutrition at which the diet is fed if the level is held at

an approximately constant percentage of ordinary ad libitum feed consumption.

From a purely practical standpoint, the fundamental principle of increase in body weight in relation to the amount of feed consumed during about the first 6 weeks may be stated in either one of the following two ways: (1) The average live weight of chickens at any time during this period could be estimated with reasonable accuracy from a knowledge of the amount of feed consumed; (2) the average weight of the chickens enables one to estimate with reasonable accuracy the amount of feed they have consumed. After about the first 6 weeks the proportion of the total diet that is utilized for growth decreases relatively, although, of course, the absolute amount of the nutrients required for maintenance and for growth increases as the birds increase in size.

Quantitative Requirements for Growth.—At the present time, scientific knowledge is rather limited with respect to the exact requirements of the different nutrients to promote optimum growth. It is true, of course, that during the last few years considerable knowledge has been gained concerning the minimum requirements of protein, minerals, and vitamins during different segments of the growth period, but the optimum requirements have yet to be determined. That the gross requirements of energy, protein, and minerals increase as growth continues is clearly shown in the following table, the data being made available by the Cambridge School of Agriculture in England.

TABLE 35.—THE COMPOSITION OF WHITE LEGHORNS AT DIFFERENT AGES (Halnan, 1936)

Composition	Age, weeks							
	1	3	7	11	15	20	24	28
Energy (100 cal.)	0.7	1.7	3.4	6.2	14.8	20.5	24.4	32.1
Protein, grams	6.9	17.2	45.4	84.0	223.5	282.8	338.0	376.0
Ash, grams	1.0	3.0	9.5	17.3	45.5	64.8	90.0	95.0

When the amount of feed consumed for each of the different periods was considered in relation to the amounts of energy, protein, and ash stored up in the body, it was found that as far as energy requirements are concerned the normal increase in feed consumption allows for the extra energy stored in the later stages of growth without the necessity of increasing the proportion of energy in the feed.

As far as the quantitative requirements of protein are concerned, it was found that the demands of the growing chick for protein are relatively high up to about 12 weeks.

The ash (mineral) content of the body increases perceptibly, but in relation to feed consumption it was found that from about the eleventh to the twenty-fourth week special consideration should be given to the mineral supply.

Apparently, special attention should be given to the supply of protein during the early stages of growth and to the mineral supply during the later stages. In addition, it may be said that special attention must also be given to the requirements of certain vitamins during the entire period of growth.

Energy Requirements for Growth.—On the basis of per unit of body weight, the amount of energy represented by the growth tissue formed decreases with age, but the amount of energy stored per unit of increase in body weight increases with age.

The sum of the energy of the tissue formed plus the basal metabolism increased by a factor for activity constitutes the net-energy requirement for growth. Data for calculating the energy content of tissue formed and basal metabolism figures were obtained from experiments conducted at the Illinois Agricultural Experiment Station. The average daily expenditure in muscular activity was estimated to be 50 per cent of the basal heat. The data for White Leghorn cockerels are given in the accompanying table. The data in the column headed "Maintenance" denote the basal metabolism, and the data headed "Equivalent weight of corn, g." convert the total net energy requirements in calories into grams of corn, which is assumed to have a net-energy value of 280 cal. per 100 g.

TABLE 36.—NET-ENERGY REQUIREMENTS OF GROWING WHITE LEGHORN COCKERELS (Mitchell, Card, and Hamilton, 1931)

Body weight, pounds	Net energy, calories				Equivalent weight of corn, grams
	Maintenance	Activity	Growth	Total	
0.5	37	18	15	70	25
1.0	55	27	19	101	36
1.5	59	29	21	109	39
2.0	72	36	21	129	46
3.0	94	47	19	160	57
4.0	114	57	14	185	66
5.0	133	66	10	210	75

The data in the table show that for the body weights above 2 lb. the energy requirements for growth decrease as the body weight increases, which is accounted for by the decreased rate of growth. The data are given here merely to illustrate a method of computing energy requirements, but it is recognized that before they can be adopted for practice they must be tested by carefully controlled feeding experiments.

Protein Requirements for Growth.—The increase in body size as the result of true growth is largely due to increases in water and protein. In a well-balanced diet its protein content is the outstanding factor that determines the rate of growth attained. The actual amount of protein required for optimum growth is considerably in excess of the amount stored in the body because the loss of protein in digestion and the wastage of protein in metabolism must be provided for in the diet.

Moreover, the amount of protein required for growth is determined to some extent by the nutritive value of the protein intake. The efficiency or biological value of the protein of a given diet is measured as the

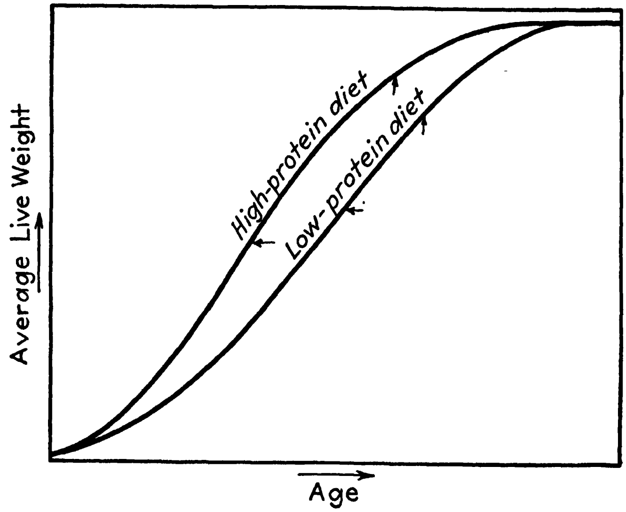


FIG. 125.—A diet high in good quality protein speeds up the rate of growth. This illustration shows typical curves resulting from the plotting of the average live weight of a group of chickens against the age of the chickens. The horizontal arrows pointing toward each curve indicate the point of inflection of the growth curves, and the vertical arrows indicate the approximate age at which egg production begins. (*Titus and Hammond*, 1935.)

percentage of the total intake that is stored. It has been pointed out previously that the various protein supplements vary considerably among themselves with respect to their biological values for growth-promoting purposes.

Animal products are for the most part superior to plant products as sources of protein. Milk, liver, and other glandular organs are superior to grass and other leafy products as well as cereal seeds, which, however, are superior to such animal products as blood and connective tissue. Because of these differences among feeds used as supplementary sources of protein, it is apparent that there can be no fixed minimum requirement for growth except in terms of specific feeds. Then, again, the fact should be kept in mind that certain proteins mutually supplement each other, so that the resulting amino-acid mixture has a biological value exceeding that of either protein when fed separately.

The results of experimental work on protein requirements for growth carried on at different institutions may be summarized in a very general way by citing the results secured with White Leghorns at Cornell University. Four diets containing approximately 20, 18, 15, and 13 per cent protein, respectively, the protein supplement used being meat scraps, were tested. At the end of 8 weeks the average weight of both sexes in grams per chick was approximately 439, 416, 308, and 247, respectively.

The 20 per cent protein diet promoted slightly faster growth than the 18 per cent one, which in turn promoted considerably faster growth than the 15 per cent protein diet, the latter promoting much faster growth than the 13 per cent one.

At the end of the 8-week period the cockerels were separated from the pullets, the latter being continued in the experiment up to the end of 20 weeks, at which time the average weight in grams per pullet for the 20, 18, 15, and 13 per cent protein diets was approximately 1,270, 1,225, 1,195, and 1,019, respectively. During the last 12 weeks of the experiment the pullets on the 15 and 13 per cent protein diets grew relatively faster than the pullets on the 20 and 18 per cent diets.

The relationship between the per cent of protein in the diet and the gain in body weight per gram of feed and per gram of protein, respectively, is brought out by the data in the accompanying table, the data from the 20 and 13 per cent protein diets being used.

TABLE 37.—GAIN PER GRAM OF FEED AND GAIN PER GRAM OF PROTEIN BY WHITE LEGHORNS RECEIVING DIETS CONTAINING 20 AND 13 PER CENT PROTEIN, RESPECTIVELY
(Norris and Heuser, 1930)

Age, weeks	Gain per gram of feed		Gain per gram of protein	
	20 per cent protein diet	13 per cent protein diet	20 per cent protein diet	13 per cent protein diet
1 to 4	0.325	0.238	1.60	1.85
5 to 8	0.253	0.195	1.26	1.52
9 to 12	0.195	0.183	0.96	1.42
13 to 16	0.163	0.192	0.80	1.49
17 to 20	0.098	0.125	0.48	0.97

The data in the table bring out certain essential features pertaining to the problem of protein requirements for growth. A diet containing a high protein content stimulates early growth, but the maximum live weight eventually attained is usually independent of the per cent of protein in the diet. On the other hand, birds on a high per cent protein diet attain maximum weight considerably earlier than those on a low per

cent protein diet, but the advantage of a high per cent protein diet is gradually lost after the birds are about half grown. During most of the period of active growth less feed is required to produce gains in live weight, although this advantage is gradually lost as maximum live weight is approached. An interesting fact to be kept in mind, however, is that protein is more efficiently utilized when the diet contains a low per cent of protein than when it contains a high per cent.

Finally, since the advantage of a diet containing a high per cent of protein is gradually lost after the chickens are about half grown, it would appear desirable to feed a diet relatively rich in protein for the first 8 to 12 weeks, especially if broilers are being produced, and thereafter grad-

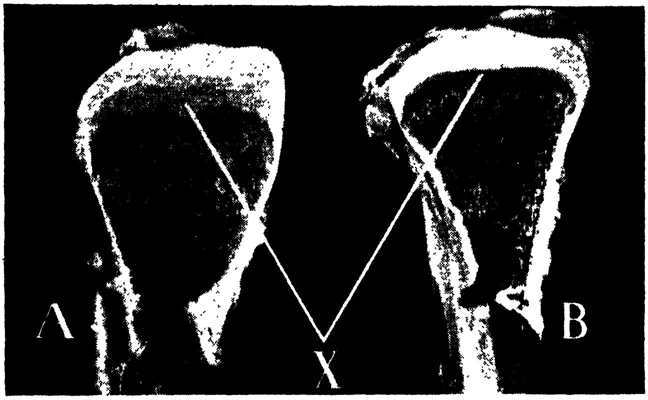


FIG. 126.—The calcium and phosphorus portions of the diet cannot be utilized efficiently in bone formation if there is a deficiency of vitamin D in the diet, the result being a bone disease called "rickets." This illustration shows the difference in the calcification of the leg bones of chicks without and with a sufficient supply of vitamin D in the diet. In *A* is shown the leg bone of a chick fed a diet in which the vitamin was not sufficient to promote proper calcification. In *B* is shown the leg bone of a chick fed the same diet to which was added ¼ of 1 per cent of sardine oil. Note at *X* the difference in the extent of the uncalcified areas. (*F. E. Booth Company, Inc.*)

ually reduce the per cent of protein in the diet as the birds grow older but not to such an extent that pullets reared will be handicapped in body weight with the onset of egg laying.

Mineral Requirements for Growth.—Of the numerous minerals that are essential in the diet to promote normal growth, the calcium and phosphorus needs have been studied most extensively because they have been found to be of such great importance for the normal development of the skeletal or bone structure of the chicken. It should be observed here, however, that the most efficient utilization of the calcium and phosphorus content of the diet depends upon an adequate supply of vitamin D. Calcium, phosphorus, and vitamin D may for convenience be called the bone-forming nutrients.

The density and strength of bone as conditioned by its calcium and phosphorus content are the real measures of proper skeletal development;

and since the ash of bone consists almost entirely of calcium and phosphorus, the determination of ash is the method commonly employed as the measure of the adequacy of bone nutrition. Since the first symptoms of mineral malnutrition usually involve the leg bones of growing chickens, ash determinations have, for the most part, been made of those bones. The results of investigations at the National Agriculture Research Center show that the tibia is the most satisfactory bone to use in studying the effects of various diets and sources of vitamin D on the ash content of bone, the epiphyseal cartilage being removed. The level of inorganic phosphorus in the blood and X-ray photographs are also useful in studying the state of the nutrition of calcium and phosphorus.

Lack of proper calcification of bone gives rise to a condition known as "rickets," in the final stages of which the chicks are unable to stand.

FIG. 127.—Typical cases of rickets, due to a deficiency of Vitamin D in the diet, this vitamin deficiency making it impossible for the chick to utilize calcium and phosphorus efficiently. (*U. S. Dept. Agr.*)

The leg bones are usually more or less brittle and are frequently curved. The breast bone is frequently curved, and the ribs often show a "beading" effect. The concentrations of calcium and phosphorus in the diet determine the ratio of the elements that permit maximum calcification. There is no calcium-to-phosphorus ratio that is optimal for all diets, even in the presence of adequate amounts of vitamin D.

As the result of numerous investigations carried on at Cornell University and at the Maryland, Ohio, and Wisconsin agricultural experiment stations, it is concluded that the average minimum requirements of calcium and phosphorus for proper bone development consist of approximately 0.70 to 0.75 per cent of calcium and approximately 0.40 to 0.50 per cent of phosphorus in the diet. On a dry-matter basis these minimum requirements approximate 0.80 per cent calcium and 0.45 per cent phosphorus. The calcium and phosphorus requirements of growing cockerels are slightly greater than those of growing pullets, and in both sexes the per cent of calcium and phosphorus in the diet decreases perceptibly as the birds approach maximum body size.

Work at the Nebraska Agricultural Experiment Station has shown that diets containing 0.90, 1.5, and 2.3 per cent of calcium resulted in the retention of 35, 24, and 13 per cent, respectively, of the ingested calcium. There was no significant change in the retention of ingested nitrogen and phosphorus. Work at the Illinois Agricultural Experiment Station has shown that both calcium and phosphorus are more efficiently utilized in a ration containing 0.50 per cent of phosphorus than a diet containing 0.26 per cent of phosphorus but that a diet of 0.83 per cent of phosphorus did not materially increase the retention of either calcium or phosphorus over the diet containing 0.50 per cent of phosphorus. The greater the consumption of a diet that results in the development of rickets the slower is the rate of bone calcification.

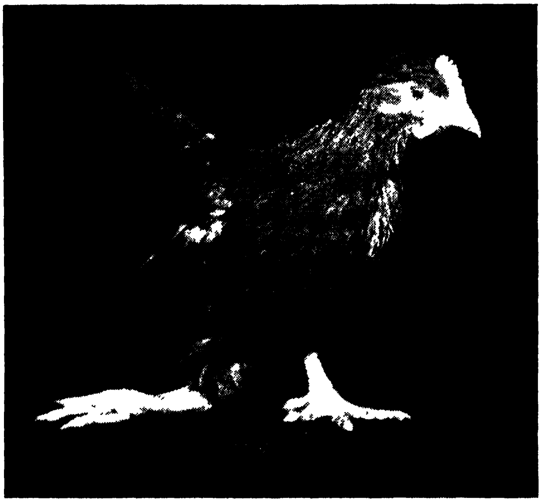


Fig. 128.—A growing chicken affected with perosis. (*Norris*, 1937.)

It should be borne in mind that 0.70 to 0.75 per cent of calcium and 0.40 to 0.50 per cent of phosphorus in the diet represent the minimum requirements for proper bone formation and for growth. The rate of growth as influenced by the other ingredients of the diet is doubtless an important factor in determining the amounts of calcium and phosphorus required. The rapid calcification of bone that takes place during the first 6 weeks under optimum conditions of growth requires a high daily intake.

A leg deformity called "perosis," or slipped tendon, is sometimes confused with rickets, in spite of the fact that the bones are well calcified and hard. The distinctive symptom of perosis is a bowing or twisting of the legs, and the Achilles' tendon slips out of its normal position and remains permanently dislocated. Frequently there is an enlargement and flattening of the tibiometatarsal joint. Excessive amounts of inorganic phosphorus or other minerals appear to be the major cause of the

disease. Oat feed, rice bran, and wheat-gray shorts have been shown to contain some factor that tended to prevent the development of perosis. Apparently at the Ontario Agricultural College manganese was first suggested as a preventive factor, and extensive research at Cornell University has shown that from 35 to 50 parts manganese per million parts feed are required to prevent perosis from developing. Work at Cornell has further indicated that manganese in the diet is necessary to enable chicks to attain optimum growth.

Very little work has been done to determine the optimum requirements for growth of other minerals, although a few general comments are possible. Bone deformities and poor growth may result from a diet containing 5 per cent or more of magnesium carbonate. Diets containing 0.5 to 1.0 per cent salt are sufficient to supply the necessary sodium and chlorine for growth, according to tests conducted at the Wisconsin Agricultural Experiment Station. Apparently there is no occasion for adding iron, copper, iodine, or most other minerals not previously discussed, to diets for growing chicks. Excessive amounts of fluorine tend to depress growth, and judging from the results secured at the Ohio and Wisconsin agricultural experiment stations the diet should not contain more than 1.5 per cent of rock phosphate. Chicks receiving 65 per cent or more of grains or their products that have been grown on seleniferous soils suffer from selenium poisoning, according to work done at the South Dakota Agricultural Experiment Station. The feeding of grit, when the diet is comprised of finely ground grains, tends to prevent the development of crater lesions in the linings of the gizzards of young chicks.

Vitamin Requirements for Growth.—During the past few years a vast amount of research work has been devoted to studying the effects on chicks of deficiencies of a number of vitamins. Although it has been demonstrated that deficiencies of certain vitamins have very pronounced effects on growth and development, much has yet to be learned concerning the optimum requirements of most of the vitamins.

The results of work carried on at several institutions indicate that from 150 to about 200 units of vitamin A per 100 g. of feed constitute the minimum requirements for growth. Results secured at Cornell University indicate that about 700 units of vitamin A are required by chicks if the optimum rate of growth is to be maintained.

The vitamin D requirements for chicks seem to have been studied most exhaustively by the Pennsylvania and Washington agricultural experiment stations. For chicks raised in confinement, without access to sunlight, it was found that about 20 International units of vitamin D from cod-liver oil should be added to each 100 g. of the diet. This is the minimum requirement for the normal calcification of bone, thus preventing rickets, and for growth. Allowance should be made, however, for differences in the calcium and phosphorus content of the diet.

The vitamin D requirements of growing chickens are readily supplied by sunlight or by exposure to ultraviolet irradiation. In most parts of

FIG. 129.—A growing chick showing symptoms of vitamin A deficiency. (*Norris*, 1937.)

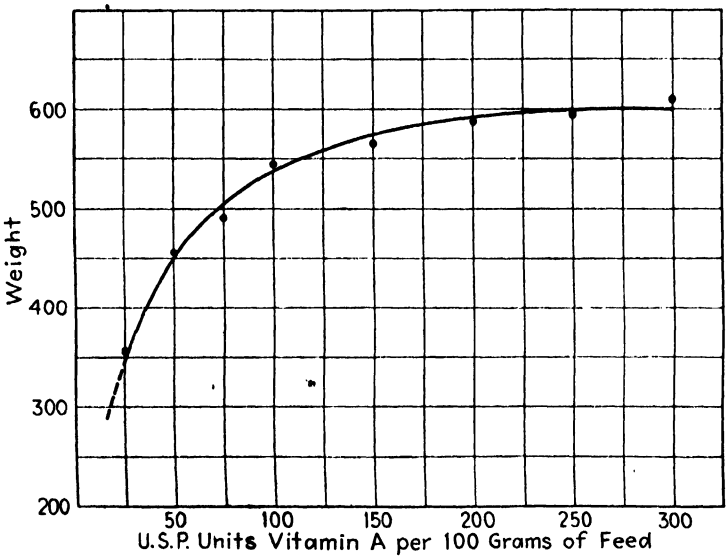


FIG. 130.—Showing the growth response of chicks to vitamin A feeding. (*Ringrose and Norris*, 1936.)

the United States if the chickens are in the sunlight a reasonable amount of time daily or every few days from May to September there is practically

no danger of rickets. Chicks exposed to the irradiation from a quartz-mercury-vapor lamp for a 3-min. period once a week did not develop

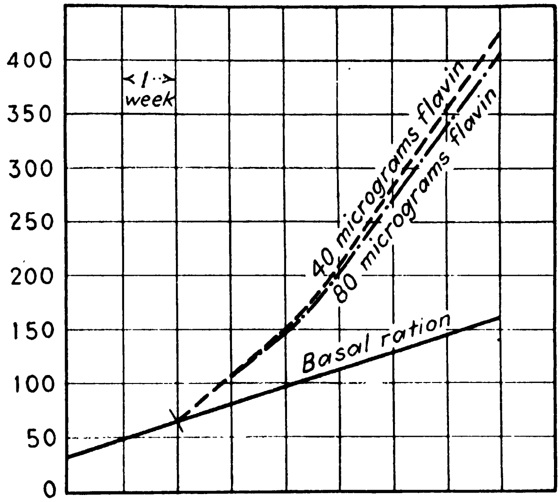


Fig. 131.—Showing the effect of feeding different levels of the riboflavin vitamin to growing chicks. (*Bethke, Record, and Wilder*, 1937.)

rickets in an experiment conducted at the Wisconsin Agricultural Experiment Station. The effects of irradiation are due to the power of ultra-

Fig. 132.—Chick suffering from a deficiency in the diet of the filtrate-factor vitamin. (*Norris*, 1937.)

violet rays serving the same function as vitamin D in relation to calcium and phosphorus metabolism. When subjected to irradiation, some

substance in the chicken's body, apparently cholosterol and ergosterol, becomes vitamin D. Irradiated ergosterol is not as effective in preventing rickets as cod-liver oil.

Riboflavin, one of the vitamin G complexes, is another vitamin essential for chick growth, work done at Cornell University indicating that the minimum requirement is equivalent to 290 units per 100 grams of feed.

The minimum requirements of the antipellagric, or filtrate-factor, vitamin appear to be 100 units per 100 g. of feed, according to results secured at the California Agricultural Experiment Station.

The minimum requirements of other vitamins that are necessary to enable chickens to make satisfactory growth have apparently not been determined.

NUTRITIVE REQUIREMENTS FOR FATTENING

A large share of the poultry meat consumed each year is marketed in the form of broilers, fryers, and roasters, all of which are sold from the producing plant while still in the growing stage. The fattening of chickens is primarily for the purpose of improving the quality of poultry meat by the addition of fat to the carcass. During growth, fat is deposited in the body to a small extent only. The fattening process leads not only to increased fat deposition but also to an increase in the deposition of water in all tissues.

The physiology of the utilization and formation of fat in the chicken's body is of fundamental importance in the raising of chickens for market. From the quantitative standpoint, the normal diet of the chicken is composed largely of carbohydrates and protein, very little fat being present. It is true that ingested protein can be transformed into body fat, the nonnitrogenous residue of certain amino acids being changed into glucose, which is readily changed into fat. Under normal conditions, however, by far the most of the fat deposit is obtained from carbohydrates plus that obtained from ingested fat fed during the fattening period. The transfer of carbohydrate into fat is much more efficiently carried out than the transfer of protein into fat.

The absorbed products of carbohydrate digestion consist of glucose and other substances which are carried to the liver where they are converted into glycogen, which in turn is gradually reconverted into glucose. The principal purpose of glycogen is to provide an easily available source of energy-producing material for use as needed by the body. When the carbohydrate intake exceeds the needs of the body for energy purposes, as in the case of fattening, sugar is transformed into fat. Much of the fat in the carcass is found immediately under the skin, the balance being located around certain organs, such as the gizzard, in the membranes surrounding the intestines, and in the muscles.

Apparently there is very little wastage in the metabolism of fat deposition. In the fattening of a mature bird approximately 7 cal. per gram of body weight increase represents the energy requirement, and approximately 0.2 g. of net protein per gram of body weight increase represents the protein requirement. The amount of energy and protein made available in the fattening diet should provide for the losses in energy that occur in digestion and the losses in protein that occur in digestion and metabolism. Aside from these brief observations on the nutritive requirements for fattening, the observations made previously concerning the nutritive requirements for growth also apply, inasmuch as most poultry is fattened during the growing period, the outstanding exception being old hens that have served their usefulness as layers.

NUTRITIVE REQUIREMENTS FOR MARKET-EGG PRODUCTION

Although the primary purpose of egg production was for the reproduction of the species, the use of eggs as human food has resulted in the development of an industry in which most of the eggs produced are used for human consumption. The production of eggs involves a complicated series of physiological events in which the body as a whole and the organs of reproduction are involved. The proper nutrition of the laying bird is of vital importance if the production of eggs of superior quality is to be maintained at a satisfactory level.

In one year a pullet or hen may produce five times as much dry matter in the eggs she lays as is contained in her body, indicating an intensive metabolism and very large nutritive requirements. It is understood, of course, that the requirements for energy, protein, carbohydrates, minerals, and vitamins are determined to a considerable extent by the rate of egg production. A hen laying an egg every day requires the necessary nutrients for those eggs and in addition sufficient nutrients for her maintenance and activity requirements, whereas another hen laying an egg every third day requires only one-third of the necessary egg-producing nutrients that are required by the first hen.

The ability to lay well is an inherited characteristic, and nutrition can do no more than allow the bird to express its maximum laying potentialities. The important point is that this can be made possible only by providing adequate diets properly balanced in all respects.

Energy Requirements for Egg Production.—From studies conducted at the National Agricultural Research Center it was estimated that 40 g. of feed were required to produce an egg over and above the gross maintenance requirements of White Leghorn hens 16 months old and weighing approximately 3.6 lb. on the average. The gross maintenance requirements of these birds was estimated to be 64 g. of feed per bird per day. This gives a total of 104 g. of feed per bird per day as the total

feed requirement for egg production. Assuming a net energy value of the feed used at 280 cal. per 100 g., the net energy value for corn, it is seen that for the production of an egg a White Leghorn hen of the size specified would require 291 cal. in her feed.

Protein Requirements for Egg Production.—At the Illinois Agricultural Experiment Station it has been estimated that the nitrogen requirement for maintenance is equivalent to 0.002 g. per calorie of heat production per square meter of body surface and that for a 4-lb. White Leghorn the maintenance requirement of dietary protein amounts to approximately 4.36 g. of corn. From studies made at Cambridge University in England it was estimated that for the production of a 2-oz. egg approximately 10.5 g. of digestible protein is required.

From the standpoint of the level of protein required in the diet to enable laying stock to maintain a satisfactory rate of egg production over a period of time, it is apparent from results secured at different institutions that the laying-stock diet should contain approximately 15 to 16 per cent protein of good quality.

It has previously been observed, however, that during about the first 8 weeks after hatching, the diet of the growing pullets should contain about 20 per cent protein of good quality. This level of protein content of the diet should be lowered from time to time until the onset of egg laying. A high level of protein of good quality throughout the entire growing period is not only unnecessary but may have the effect of inducing the pullets to start laying somewhat too early.

The results secured at two different institutions with different diets show remarkable agreement with respect to the protein level of the diet for satisfactory egg production. At Cornell University three diets each containing 12, 14, and 16 per cent of protein resulted in an average egg production of 148, 156, and 178 eggs per bird, respectively. Results secured at the Washington Agricultural Experiment Station indicated that a diet containing 15 per cent protein from adequate sources can safely be recommended for satisfactory egg production.

Mineral Requirements for Egg Production.—Among the various minerals essential for satisfactory egg production, calcium is the most important from the quantitative standpoint because the eggshell, which constitutes approximately 11 per cent of the total weight of the egg, is composed very largely of calcium carbonate. The fact that the total calcium level of the blood serum of the laying hen is approximately double that of the nonlaying hen, as observed at the New Jersey Agricultural Experiment Station and elsewhere, indicates the intensity of calcium metabolism involved in egg production.

Although a deficiency of calcium in the diet of the laying hen does not materially change the calcium content of the liquid portion of the

eggs laid, nor are soft-shelled eggs produced, as demonstrated by the Kentucky Agricultural Experiment Station, nevertheless, the percentages of calcium and phosphorus in the bones are reduced, and there is a reduction in egg production.

A deficiency of phosphorus in the diet produces comparable effects. At the Kansas Agricultural Experiment Station it was demonstrated that there was a marked rise in the level of inorganic phosphorus in the blood of laying hens during the period of shell formation. At Cambridge University it was observed that the metabolism of phosphorus is linked with that of calcium and that excessive calcium feeding may lead to the depletion of phosphorus reserves.

During heavy egg production, calcium and phosphorus are transferred from the bones, this physiological process emphasizing the importance of feeding a sufficiently high level of calcium and phosphorus during the laying period in order to provide sufficient reserves to be drawn upon. From work done at Cornell University it appears that the diet of the laying hen should contain 1.8 per cent of calcium, and from work at the Washington Agricultural Experiment Station the desirable phosphorus content appears to be 0.8 per cent.

Results secured at the National Agricultural Research Center led to the conclusion, however, that the level of calcium intake should be controlled by taking into consideration the phosphorus content of the diet, feed consumption, and the potential egg-laying capacity of the birds. The following ratios have been suggested:

Calcium		Phosphorus	Calcium		Phosphorus
1.9	:	0.6	2.4	:	1.0
2.0	:	0.7	2.5	:	1.1
2.1	:	0.8	2.6	:	1.2
2.3	:	0.9	2.8	:	1.3

The ability of the laying hen to utilize calcium and phosphorus most efficiently depends upon the presence in the diet of adequate amounts of vitamin D, this relationship having been discussed previously.

Practically nothing is known concerning either the minimum or the optimum requirements of the numerous other minerals that are considered to be essential in the diet of the laying hen.

Vitamin Requirements for Egg Production.—The amount of research that has been conducted to determine the requirements of the various vitamins for egg production is rather limited, although some interesting results have been obtained. At the Texas, New Jersey, and Western Washington agricultural experiment stations the results secured indicate that approximately 400 to 500 Sherman-Munsell units of vitamin A per 100 g. of feed are sufficient for good egg production, and the eggs are rich in the vitamin.

From results secured at the Pennsylvania and Washington agricultural experiment stations, it is apparent that approximately 60 to 80 International (U.S.P., United States Pharmacopoeia) units of vitamin D per 100 g. of feed is required to maintain a satisfactory level of egg production in the case of pullets not having access to sunlight.

Observations made at Cornell University suggest that 130 units of riboflavin per 100 g. of feed are required for satisfactory egg production.

Other vitamin requirements for egg production apparently have not been determined as yet.

Nutritive Requirements for Molting.—The periodical shedding and renewal of feathers by the laying hen presents a problem of interest from the standpoint of possible special nutritive requirements that must be met during the molting process. The close association that exists between the onset of the molt and the cessation of egg production suggests a shift in the requirements from those of egg production to those of feather growth.

Observations made at the Nebraska Agricultural Experiment Station indicate clearly the need for an adequate supply of the amino acid cystine for feather growth. It was found that with nonmolting mature Rhode Island Red hens the average daily loss of endogenous nitrogen amounted to 144 mg. per kilogram of body weight, whereas in molting hens the daily loss amounted to 219 mg. per kilogram of body weight. When 145 mg. of cystine was added to the diet of molting hens it was found that the average daily loss of endogenous nitrogen was 137 mg. in contrast with a loss of 239 mg. per kilogram of body weight with other molting hens not fed the cystine. The feeding of cystine exerted a protein-sparing effect out of proportion to its nitrogen content, thus suggesting that for normal feather growth cystine is important.

At the Texas Agricultural Experiment Station it was concluded that the vitamin A requirements for feather growth are equivalent to those for egg production.

NUTRITIVE REQUIREMENTS FOR HATCHING-EGG PRODUCTION

The results of numerous experiments carried on at different institutions during recent years have demonstrated clearly that certain diets that are quite satisfactory for market-egg production are relatively very unsatisfactory for hatching-egg production. Recent discoveries have shown that specific nutrients have specific functions in the various events involved in the reproduction of the species. The egg must contain many nutrients in adequate amounts for the proper nourishment of the embryo during the period of incubation. The hatching quality of an egg is influenced to a considerable extent by the kind of diet received by the hen that lays the egg. The results of research work indicate that the three

classes of nutrients of particular importance in the production of eggs of the highest possible hatchability include the proteins, minerals, and vitamins.

Protein Requirements for Hatchability.—A fact of outstanding importance developed by recent lines of research is that the source of protein for the diet of breeding stock sometimes has a striking effect on hatchability. Whereas laying hens fed diets containing protein of vegetable source only may lay well, their eggs usually do not hatch so well as eggs laid by breeding stock whose diets contain protein of animal as well as of vegetable origin.

Presumably the differences in hatchability are due to differences in the amino-acid composition of the vegetable and animal proteins, the vegetable proteins being deficient in certain amino acids that are known

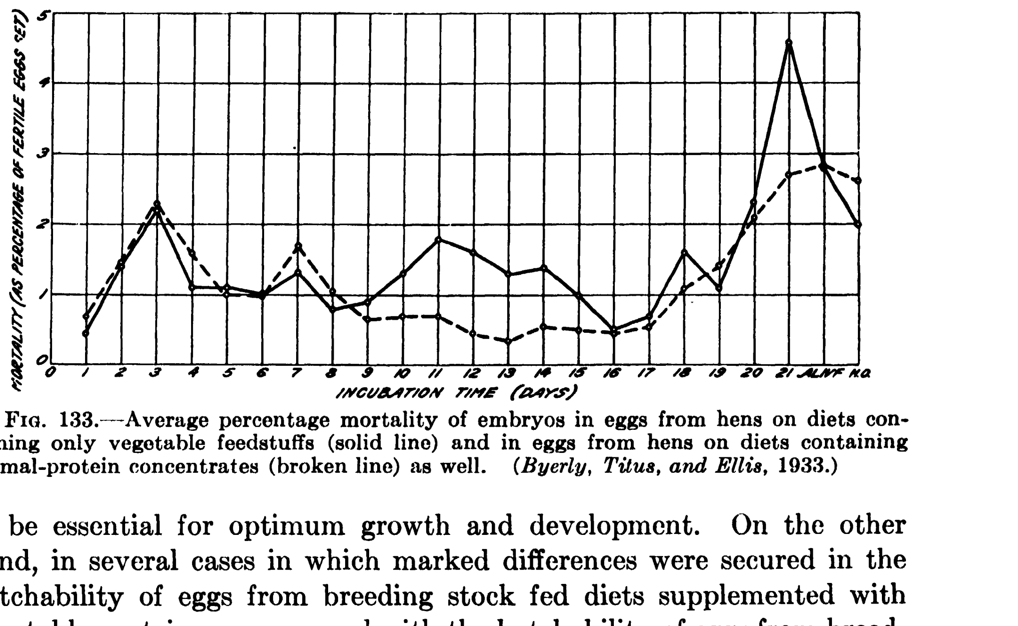


FIG. 133.—Average percentage mortality of embryos in eggs from hens on diets containing only vegetable feedstuffs (solid line) and in eggs from hens on diets containing animal-protein concentrates (broken line) as well. (*Byerly, Titus, and Ellis*, 1933.)

to be essential for optimum growth and development. On the other hand, in several cases in which marked differences were secured in the hatchability of eggs from breeding stock fed diets supplemented with vegetable proteins as compared with the hatchability of eggs from breeding stock fed diets supplemented with animal proteins, the increased hatchability reported to be due to the superiority of the animal proteins may in reality have been due to the presence of vitamins and minerals that several animal feeds contain.

At the California Agricultural Experiment Station no significant differences were observed in the amount of total nitrogen, total amino nitrogen, cystine, tyrosine, and tryptophan between the eggs of high hatchability and the eggs of low hatchability.

The results secured from other lines of research indicate that the source of origin or methods of manufacture determine the value of protein supplements for hatchability. For instance, at the National Agricultural

Research Center it was found that different processes employed in the manufacture of beef products affected their value for the production of hatching eggs.

Mineral Requirements for Hatchability.—Since the shell of the egg serves as an important source of calcium for the developing embryo, it would seem reasonable to expect that diets deficient in calcium would affect hatchability adversely. Such was demonstrated to be the case at the Kentucky Agricultural Experiment Station. The requirements of breeding stock for calcium and phosphorus are apparently about the same as those of laying stock. That a high level of calcium may have a detrimental affect on hatchability was shown by some results secured at the National Agricultural Research Center. It was found that the hatchability of the eggs of both hens and pullets tended to be the lowest on the two highest levels of calcium intake, the per cent of calcium in the diet being 4.05 and 5.40, respectively. These high levels of calcium intake affected the hatchability more adversely when the phosphorus level was 0.9 per cent than when it was 1.2 per cent of the diet. The increase in embryonic mortality occurred chiefly during the last 3 days of incubation.

From the results secured at Cornell University there was some indication that diets for breeding stock may sometimes be deficient in manganese.

Work at the Minnesota Agricultural Experiment Station showed that supplementary iodine is not required in the diet of breeding hens.

Vitamin Requirements for Hatchability.—Beyond the requirements of certain vitamins for satisfactory market-egg production, there are particular requirements of certain of the vitamins for satisfactory hatching-egg production. It has been demonstrated from work done at various institutions that a deficiency of almost any vitamin will adversely affect hatchability but that, with certain exceptions, if enough of the vitamin is supplied to promote satisfactory market-egg production the hatchability of the eggs is usually satisfactory.

Studies on the vitamin A requirements for hatchability indicate that it tends to increase as the proportion of vitamin A in the diet is increased up to about 500 Sherman-Munsell units per 100 g. of feed. Dark-colored yolks are richer in carotene and xanthophyll than light-colored yolks, and recent Russian research work has indicated that the darker the yolk color of eggs the better the hatchability.

Chicks hatched from eggs laid by birds receiving inadequate amounts of vitamin B are likely to exhibit symptoms characteristic of polyneuritis.

Vitamin D in sufficient quantities must be fed the breeding stock, or the hatchability of eggs will suffer. The vitamin must be supplied through the feed or its precursor, or the breeding stock must be exposed

to direct sunlight or to ultraviolet radiation. The blood calcium of hens receiving insufficient amounts of vitamin D falls below the normal level, and the eggs produced are inclined to be small, the relative shell weight and ash content of the shell are reduced, and hatchability is decreased.

The results secured that gave rise to these findings are given in the table, on page 282, the work having been done at the Pennsylvania Agricultural Experiment Station. The data show that the diets ranging from 58 to 116 U.S.P. units of vitamin D per 100 g. of feed gave the best

FIG. 134.—Chick suffering severely from a lack of vitamin B. (*Norris*, 1937.)

results in hatchability for hens in confinement. The data also show that birds on range without additional supplies of vitamin D in their diet produced eggs that hatched somewhat better than the confined birds that received up to 155 U.S.P. units of vitamin D per 100 g. of feed.

Work carried on at the Washington Agricultural Experiment Station led to the conclusion that breeding stock in strict confinement without access to sunlight required 135 U.S.P. units of vitamin D per 100 g. of feed. From Dec. 10 to Mar. 4 with pullets having access to sunlight it was found necessary to supplement the diet with 34 U.S.P. units of vitamin D to secure best results in hatchability. For the rest of the year it was not necessary to supplement the diet of these unconfined birds with vitamin D.

A deficiency of vitamin D in the diet of the breeding stock prevents the embryos in the incubated eggs from securing adequate amounts of calcium and phosphorus, as demonstrated by the results secured at the Kentucky Agricultural Experiment Station. On the other hand, excessive amounts of vitamin D tend to depress hatchability, according to

results secured at the Ontario Agricultural College and the National Agricultural Research Center.

The results secured from experiments conducted at the Illinois Agricultural Experiment Station and the National Agricultural Research Center have shown that vitamin E is essential in the diet of breeding stock for successful reproduction.

According to the results secured at Cornell University the riboflavin requirements for satisfactory hatchability amount to 230 units per 100 gm. of feed.

TABLE 38.—HATCHABILITY AND OTHER CHARACTERISTICS IN RELATION TO THE VITAMIN D CONTENT OF THE BREEDING-STOCK DIET
(Murphy, Hunter, and Knandel, 1936)

Character	Year	U.S.P. units of vitamin D fed per 100 g. of feed							
		Birds in confinement						Birds on range	
		19	39	58	78	116	155	0	39
Average weight of eggs, grams.	1932 to 1933	50.9	51.7	52.7	52.3	52.7	52.3	53.1	52.9
	1934 to 1935	43.1	46.2	48.4	49.8	50.7	50.5	51.2	51.0
Average blood-serum calcium of laying hens. Calcium, milligrams per 100 cc. blood serum.	1932 to 1933	21.4	24.3	24.7	25.5	26.0	25.2	26.6	25.5
	1934 to 1935	21.2	21.9	23.3	24.5	26.2	25.6	27.3	28.2
Average shell weight of total egg weight, per cent.	1932 to 1933	7.0	8.7	8.9	8.8	9.0	9.2	9.1	9.0
	1934 to 1935	6.1	7.3	8.1	8.5	8.9	8.8	9.1	9.2
Average ash content of egg shell, per cent.	1932 to 1933	52.4	53.0	53.3	53.2	53.2	53.2	53.2	53.1
	1934 to 1935	51.7	52.6	53.0	53.2	53.4	53.5	53.4	53.3
Average hatch of fertile eggs, per cent.	1932 to 1933	44.5	74.6	84.5	84.9	88.1	87.8	91.0	83.3
	1934 to 1935	11.1	37.8	77.4	77.7	79.6	74.2	86.5	77.1

Summary Statement on Nutrient Requirements.—In the previous pages the minimum requirements of the various nutrients have been given in so far as they have been determined at the state experiment stations and other institutions. Much more research is needed in order to determine the optimum amounts of each of the nutrients required for different purposes. In fact, more research would be in order for the purpose of determining more definitely the minimum requirements of several of the nutrients. This is particularly true with respect to the various vitamins, research pertaining to which may be said to be in the embryo stage of development.

Although the optimum requirements of the various nutrients for different purposes have not been definitely determined, perhaps the

following table will serve as a general summarization of the approximate needs of the different classes of chickens for a number of the more important nutrients. The reader should realize, however, that the figures in this table are subject to modification as the result of much more intensive research.

TABLE 39.—PROBABLE REQUIREMENTS OF SEVERAL NUTRIENTS BY DIFFERENT CLASSES OF CHICKENS
(Titus, 1937)

Class of chicken	Protein, per cent of total feed	P, per cent of total feed	Ca, per cent of total feed	A, Int. units per 100 g. of feed	B, Int. units per 100 g. of feed	D, A.O.A.C. units per 100 g. of feed[1]	Riboflavin, Cornell units per 100 g. of feed
Growing stock	21	0.7	1.1	320	40	40	350
Laying stock	18	1.0	2.4	700	40	80	145
Female breeding stock	18	1.0	2.4	1040	40	120	265
Male breeding stock	13	0.4	0.5	160	40	16	110

[1] An A.O.A.C. of vitamin D is equivalent to an International or U.S.P. unit, if obtained from cod-liver oil.

The data in this table serve the purpose, at least, of giving a general picture of the relative needs, for a number of the nutrients, of chickens used for different purposes.

A list of selected literature references will be found at the end of the next chapter.

CHAPTER IX

FEEDING PRACTICE

The various nutrients that have been found to be essential in the nutrition of poultry are widely distributed in the plant and animal kingdoms. Although many plant and animal products used in feeding poultry each contain many of the essential nutrients, the proportion in which these nutrients occur often varies widely, especially as between plant and animal products. Moreover, plants and cereal grains differ among themselves with respect to their chemical composition, and animal products often differ very widely in chemical composition depending upon their origin and method of being processed for feeding purposes.

DIFFERENT FEEDS CONTAIN QUANTITATIVELY AND QUALITATIVELY DIFFERENT NUTRIENTS

In the feeding of poultry, a feed is usually used as the chief source of a certain nutrient, although it may also contain other nutrients in considerable proportion. In the preparation of poultry diets for any particular purpose the chief sources of the essential nutrients should always be kept in mind. The approximate composition of numerous feeds used in preparing diets for poultry is given here largely for the purpose of acquainting the reader with the similarity of composition of many feeds as well as indicating the outstanding differences in composition among some of the feeds. It should be borne in mind, of course, that feeding tests are necessary to determine the nutritive value of any particular feed or mixture of feeds. The chemical composition of a feed does not indicate the extent to which the different nutrients are utilized by the fowl.

Sources of Water.—The cereal grains that make up the largest share of the poultry diet contain on the average from about 8 to about 12 per cent of their air-dry weight in the form of water and, therefore, do not supply nearly enough water in proportion to the needs for growth, maintenance, fattening, or egg production.

Additional water must be supplied, and this is usually accomplished by making available liberal quantities of well, spring, river, or rain water. Deep-well water is invariably harder than rain water and, within the same geological formations, is also harder than lake or river water. Water containing alkalies is apt to be more harmful than water containing

TABLE 40.—AVERAGE COMPOSITION OF POULTRY FEEDS

Feed	Moisture, per cent	Ash, per cent	Protein, per cent	Carbohydrates		Fat, per cent
				Fiber, per cent	Nitrogen-free extract,* per cent	
Grains and seeds:						
Barley	9.6	2.9	12.8	5.5	66.9	2.3
Barley meal	9.6	2.9	12.8	5.5	66.9	2.3
Bread	33.8	1.5	7.9	0.7	55.4	0.7
Brewers' grain (dried)	6.8	3.6	26.9	14.3	41.4	7.0
Broomcorn	11.8	2.9	10.2	8.2	63.5	3.4
Buckwheat	12.6	2.0	10.0	8.7	64.5	2.2
Buckwheat middlings	12.0	4.8	28.3	4.8	42.7	7.4
Coconut meal (O. P.)	7.3	5.5	21.3	9.4	46.5	10.0
Corn	12.9	1.3	9.3	1.9	70.3	4.3
Corn bran	10.3	2.4	9.9	10.4	59.7	7.3
Ground-ear corn	15.6	1.5	8.3	6.8	64.4	3.4
Corn-gluten feed	9.2	3.6	25.1	7.3	51.9	2.9
Corn-gluten meal	9.0	1.3	40.9	3.2	44.5	1.1
Cornmeal or chops	12.9	1.3	9.3	1.9	70.3	4.3
Cottonseed meal (prime)	6.9	5.9	38.8	12.2	29.4	6.8
Cowpeas	9.8	3.6	23.8	4.3	57.1	1.4
Durra	9.9	2.0	10.1	1.7	72.8	3.5
Feterita	11.1	1.5	12.5	1.7	70.1	3.1
Field peas	9.2	3.4	22.9	5.6	57.8	1.1
Flaxseed	9.2	4.3	22.6	7.1	23.2	33.7
Flour middlings	10.7	3.7	17.8	4.7	58.1	5.0
"Red Dog" flour	10.1	2.9	17.2	3.1	61.9	4.8
Garden peas	11.8	3.0	25.6	4.4	53.6	1.6
Hempseed	8.0	2.0	10.0	14.0	45.0	21.0
Hominy feed	8.3	2.9	10.9	4.6	65.5	7.7
Kafir	9.4	1.6	11.1	2.1	72.6	3.2
Linseed meal (O. P.)	8.9	5.4	34.5	7.7	36.7	6.8
Malt sprouts	7.8	5.7	25.9	12.4	46.9	1.3
Millet	10.8	3.6	12.1	8.4	16.0	4.1
Milo	10.7	2.8	10.7	2.4	70.5	2.9
Navy beans	13.4	3.6	22.7	5.8	53.0	1.5
Oats or ground oats	7.7	3.5	12.5	11.2	60.7	4.4
Peanuts (hulls on)	6.0	2.8	24.7	18.0	15.4	33.1
Peanut kernels	5.5	2.3	30.2	2.8	11.6	47.6
Peanut meal (no hulls)	6.2	4.9	49.3	6.3	22.5	10.8
Rice (polished)	12.3	0.5	7.4	0.4	79.0	0.4
Rye	9.5	1.9	11.1	2.1	73.7	1.7
Rye feed	10.2	4.0	15.6	4.3	62.7	3.2
Soybeans	6.4	4.8	39.1	5.2	25.8	18.7
Soybean meal	6.1	5.6	47.1	5.7	27.7	7.8
Shallu	9.7	1.6	12.5	1.7	71.1	3.4
Sunflower seed	6.9	3.1	16.1	27.9	21.3	24.7
Velvet beans	9.8	3.1	26.2	6.0	50.1	4.8
Wheat	10.6	1.8	12.3	2.4	71.1	1.8
Wheat bran	9.6	5.9	16.2	8.5	55.6	4.2
Wheat flour	12.3	0.5	10.9	0.4	74.6	1.8
Wheat middlings (shorts)	10.1	3.5	16.3	4.3	61.6	4.2
Wheat screenings	10.2	3.9	13.3	7.4	61.1	4.1
Feeds of animal origin:						
Blood meal	9.7	3.3	82.3	....	3.8	0.9
Bone meal	7.2	61.5	23.1	3.3	....	4.9
Bone meal (steamed)	4.1	70.0	4.9	....	....	0.5
Buttermilk	91.0	0.7	3.0	....	4.8	0.5
Buttermilk, condensed	71.5	3.3	11.5	....	10.4	3.3
Buttermilk, dried	4.5	8.1	34.6	....	48.3	4.5
Fish meal	6.6	21.0	56.1	0.7	2.6	10.5
Fresh bone	30.4	21.1	19.7	....	3.8	25.0
Meat scrap (50 to 55 per cent protein)	7.1	21.1	53.9	2.2	5.0	10.7
Pork cracklings	5.0	2.3	56.4	....	4.1	32.2
Skim milk	90.6	0.7	3.2	....	5.2	0.3
Skim, milk, dried	4.7	7.3	37.0	....	50.0	1.0
Tankage	7.6	22.2	53.7	1.8	3.8	10.9
Whey	93.8	0.4	.6	....	5.1	0.1
Green feeds, etc.:						
Alfalfa (green)	72.9	2.6	4.7	8.0	11.0	0.8
Alfalfa-leaf meal	5.6	14.2	20.5	15.2	41.1	3.2
Alfalfa meal or alfalfa hay (dried)	8.3	8.9	16.0	27.1	37.1	2.6
Beet pulp (dried)	8.4	3.5	9.3	18.7	59.3	0.8
Cabbage	91.1	0.8	2.2	0.9	4.7	0.3
Cane molasses	24.5	6.8	3.1	....	66.1	
Carrots	88.6	1.0	1.1	1.3	7.6	0.4
Kale	88.7	1.9	2.4	1.5	5.0	0.5
Mangels	91.2	1.0	1.4	0.8	5.4	0.2
Potatoes	78.9	1.0	2.1	0.6	16.3	0.1
Rape	85.7	2.0	2.4	2.2	7.1	0.6
Red-clover hay (dried)	12.9	6.9	13.6	24.1	39.1	3.4
Rutabagas	88.6	1.2	1.2	1.3	7.5	0.2
Turnips	90.6	0.8	1.3	1.2	5.9	0.2

* The nitrogen-free extract is regarded as the digestible carbohydrate portion of a feed.

neutral salts. Water containing excessive amounts of such minerals as fluorine and selenium is toxic in its effect.

Sources of Carbohydrates.—The cereal grains constitute the chief source of carbohydrates in poultry diets, although proteins, fats, and minerals are also present. Being relatively rich in carbohydrates, the cereal grains constitute the chief source of energy in the diet. The various whole grains most commonly used in poultry feeding have approximately equal feeding value when compared pound for pound on a fiber-free basis. One outstanding exception with respect to their relative feeding value is the vitamin A potency of yellow corn. As sources of carbohydrates, however, barley, corn, oats, and wheat are quite comparable from the standpoint of feeding value, although other properties these grains possess sometimes determine the extent to which each should be used in the diet.

✓*Barley.*—This cereal is an excellent feed for poultry, though not quite so palatable as corn or wheat. Moreover, heavy-weight barley is more palatable than light-weight barley. It contains more digestible organic matter than oats but not so much as corn. Scabbed barley has been found as satisfactory for poultry-feeding purposes as normal barley.

Barley meal is sometimes used in fattening poultry, in which case heavy-weight grain should be used, and it should be ground evenly, or the hulls may cause trouble in the chicken's crop.

Buckwheat.—Because of its high fiber content, color, and relative unpalatability, buckwheat is rarely used in feeding poultry except sometimes in the form of buckwheat middlings for fattening.

Corn.—Since it is the most abundant grain produced in the country, and since it is very palatable and readily digested, corn is one of the most valuable sources of carbohydrates. Yellow corn contains xanthophyll and supplies vitamin A and is therefore superior as a feed to white corn.

Cornmeal (ground whole corn) has the same feeding value as the whole grain and is used extensively in fattening diets as well as for growing chicks and laying hens.

Corn hominy is made up of the hull, germ, and part of the starch cells and is a good poultry feed.

Emmer.—This grain may be used to replace a small portion of corn in the diet, depending upon the price of each.

Feterita.—This is another grain sorghum which may be substituted for a limited portion of yellow corn, especially where the latter is difficult to secure.

Hegari.—Another grain sorghum which may be used to replace yellow corn in diets that are otherwise properly balanced.

Kafir.—This grain sorghum is grown extensively in certain sections of the country and is frequently substituted for yellow corn with satisfactory results. ज्वार, बाजरी, कांगणी, कोद्रू.

Millet.—This grain can also be used to a limited extent as a substitute for yellow corn, provided the diet contains the proper minerals.

Milo.—Although milo is not so palatable as kafir, it can be used as a substitute for approximately 50 per cent of the yellow corn in a well-balanced diet.

Oats.—Whole oats are relatively higher in fiber content than corn, wheat, and barley but can be used in diets that are otherwise low in fiber content. Oats of poor quality should never be used.

Finely ground oats are sometimes used in mashes, especially for fattening purposes.

Rice.—Because of its relatively high carbohydrate content and high digestibility, rice is a satisfactory feed for poultry, and in addition it has a regulating effect on the bowels. Its use in poultry diet is limited, however, because it is in such demand by human beings.

Rye.—Although comparing favorably with wheat in composition, rye is not a palatable feed and, if fed in considerable quantities, sometimes causes digestive disorders. The droppings often contain a pasty material so that the feces tend to cling to the chickens' feet.

Wheat.—This cereal is extensively grown and is widely used as a source of carbohydrates because of its palatability and ease of digestibility. Soft wheats are as valuable for poultry feeding purposes as hard wheats. Shrunken wheat, provided it is not so badly shrunken as to affect its palatability, can often be used to good advantage because much of it is not suitable for milling purposes.

Wheat bran consists of the outer layer of the wheat kernel and is used extensively in adding bulk to the diet. It also has laxative properties but is low in the digestibility of its organic matter. Because of its comparatively low feeding value, too much bran should not be used.

Wheat middlings contain a higher percentage of carbohydrates and fats and less fiber than wheat bran. As turned out from the mills, different lots of wheat middlings may vary widely in their feeding value.

Wheat screenings are low grades of wheat frequently mixed with foreign materials, particularly weed seeds. They are usually of questionable value unless of very high quality, *i.e.*, free from impurities and weed seeds having toxic properties.

Wheat shorts are very similar to wheat middlings. Shorts comprise the outer portions of the wheat kernel, except the outer layer which goes to make bran.

Miscellaneous Carbohydrate Feeds.—Other feeds relatively rich in carbohydrates include *potatoes*, *molasses*, *dried skim milk*, *dried buttermilk*, and some of the "green feeds."

Cheap *potatoes* may be used to some extent as a supplement to the mash ration in feeding laying hens and in fattening chickens for market. Some work has been done to determine the value of *molasses* in feeding poultry, but its place in the feeding of chickens has not been well established, although it is a good source of one of the vitamins. While it is true that *dried skim milk* and *dried buttermilk*, as well as some of the green feeds, contain considerable amounts of carbohydrates, these feeds are fed to chickens primarily for other purposes, and a discussion of the particular purpose they serve is given in appropriate sections.

Sources of Vegetable-protein Supplements.—The most prominent component of the body of the fowl, aside from water, is protein. It is the basis of muscular and glandular tissue. Moreover, the egg contains a higher percentage of protein than the majority of the cereal grains. Then again, the fact should be kept in mind that a portion of the protein of the cereal grains remains undigested when fed to chickens.

Zein is the protein of corn, but zein is deficient in two essential amino acids, lysine and tryptophane. It is obvious, therefore, that corn is lacking in the quality of its protein and is also deficient in quantity. This is true of most other cereals.

TABLE 41.—PER CENT OF TOTAL NITROGEN IN THE FORM OF AMINO ACIDS IN VARIOUS PROTEINS
(Mitchell and Hamilton, 1929)

Source of protein	Per cent of total nitrogen				
	Arginine	Cystine	Histidine	Lysine	Tryptophane
Zein (corn)	3.6	0.5 to 0.6	1.3 to 2.1	0.1	0.0 to 0.14
Gliadin (wheat)	4.7	1.6	4.3	1.6	0.6 to 0.8
Avenalin (oat)	15.0	1.0	8.3	3.5	0.9
Hordein (barley)	5.4	1.0	1.6 to 3.6	1.0	0.6 to 0.8
Casein (milk)	7.4	0.2	6.2	10.3	1.9
Myosin from muscle (hen)	17.3	1.6	6.7	9.0	
Myogen from muscle (hen)	18.1	1.2	6.6	10.1	
Yolk (hen egg)	14.5	....	3.1	9.4	1.1 to 1.5
White (hen egg)	11.7	....	0.2 to 4.0	10.1	1.1 to 1.2

It is easy to understand, therefore, that protein is not only one of the most important of all of the requirements in the feeding of poultry but also that the source of the proteins is an important matter. Moreover,

the proteins of practically all cereals require to be supplemented by other feeds relatively rich in protein containing the right kind of amino acids.

Brewers' dried grains contain an average of about 25 per cent protein but because of their relatively high fiber content are of limited value in the poultry diet.

Coconut meal is a by-product in the manufacture of coconut oil and is relatively rich in protein, though practically no work has been done to determine its value as a poultry feed.

Corn-gluten feed is a by-product in the manufacture of glucose and cornstarch. The kernels of corn are soaked and separated into hull, germ, starch, and gluten; and the gluten is then dried. The hull and gluten are mixed while still wet; and the mixture is then dried, ground, and sold as corn-gluten feed.

Corn-gluten meal consists chiefly of the corn gluten separated in the wet-milling process of starch manufacture with few if any hull fragments.

Cottonseed Meal.—Cottonseed meal is a by-product of the cotton industry and is relatively rich in protein. It may be used up to about 6 per cent of the diet, but beyond that there is a tendency for the yolks of eggs laid by hens fed cottonseed meal to be discolored, especially after the eggs have been in storage for a few months. The discoloration of the yolks appears to be due to the free or bound gossypol contained in cottonseed meal.

Cowpeas are not only rich in protein but contain some of the essential amino acids lacking in the cereal grains. However, they are not very palatable and are used to a limited extent only.

Distillers' corn-dried grains usually contain about 30 per cent protein, are relatively rich in fat, but are rather bulky to be used extensively in the poultry diet.

Linseed-oil meal is obtained from flaxseed after the extraction of the linseed oil. "Old-process" linseed-oil meal, designated "O. P.," is the residue of the flaxseed left when the oil has been expressed by hydraulic pressure. "New-process" linseed-oil meal, designated "N. P.," is the residue left after the oil has been dissolved out of the crushed and heated flaxseed by the use of naphtha. The new process meal, therefore, contains less fat than the old process meal, though both are relatively rich in protein.

Peanut meal is a by-product in the manufacture of peanut oil. It may be used to a limited extent as a protein supplement for egg production or growth when proper minerals are fed in addition.

Soybean-oil meal is obtained from the manufacture of soybean oil and is relatively rich in proteins. Soybean-oil meal supplemented with minerals can apparently be used in diets for growing chicks when it provides not more than 75 per cent of the protein supplements.

Soybeans have not been used extensively in poultry feeding, although certain varieties have been shown to contain proteins suitable for producing good-quality hatching eggs.

Sources of Animal-protein Supplements.—Inasmuch as all proteins of plant origin are more or less comparable with respect to their amino-acid content, it is clear that the vegetable-protein supplements cannot be expected to provide for all of the amino-acid deficiencies occurring in the proteins of the cereal grains. Protein supplements of animal origin, in many cases, supply the amino-acid deficiencies existing in proteins of plant origin. A diet containing proteins of animal origin is more likely to be properly balanced from the standpoint of its amino-acid content than one made up entirely of proteins of plant origin.

Blood, either fresh or dried, is not used extensively in feeding poultry. Fresh blood is sometimes used in wet mashes. Dried blood does not seem to be palatable and apparently should be used to a limited extent only, if at all.

Crab-scrap meal is used to a limited extent only in the feeding of poultry, apparently partly because it is not so high in protein content as many other animal protein supplements and also because it has been found that the proteins are not so readily utilized.

Cracklings usually have a high fat content, and in many cases the protein is apt to be low in quality.

Fish meal and Fish scrap are by-products of the fishing industry. White fish meal is produced principally from the waste of edible fish such as the cod, halibut, and haddock or from the whole fish. Oily fish meal is produced usually from the whole body of the herring, menhaden, pilchard, sardines, and mackerel. Also, salmon meal is made from the offal of the salmon. Fish scraps, on the other hand, usually contain a larger percentage of the heads, tails, and scales of fish than fish meal and are of doubtful value in the feeding of poultry. Vacuum-dried white fish meals have been found to be superior to flame-dried meals. Commercial brands of fish meal must not contain over 7 per cent common salt ($NaCl$).

Insects.—Fowls on range usually have access to large numbers of insects, which have a high protein content.

Liver Meal.—Not only are liver meals high in protein content, but they also contain certain vitamins that are of value in promoting growth and obtaining high hatchability.

Meat meal is of high feeding value as a protein supplement but is not so readily available as meat scraps.

Meat and Bone Meal.—This by-product of the packing-house industry is made by tanking under live steam or by dry rendering or by both processes the residue of animal tissues exclusive of horn, hoof, manure, and

stomach contents, except portions unavoidably included. It contains more than 10 per cent of phosphoric acid.

Meat Scraps.—This product is used extensively in poultry diets as a protein supplement and consists of the dry-rendered residue from animal tissues exclusive of horn, hoof, manure, and stomach contents, except portions unavoidably included. Meat scraps must not contain over 10 per cent phosphoric acid, and most brands are guaranteed to contain not less than 50 per cent protein.

Milk Products.—The principal milk products used in poultry feeding include *liquid skim milk, dried skim milk, condensed buttermilk, dried buttermilk,* and *dried whey.* One pound of dried milk is equivalent to approximately 3 lb. of condensed milk, and 1 lb. of condensed milk is equivalent to approximately 3 lb. of liquid milk. The various milk products contain proteins that are easily digested and are of considerable value.

Shrimp Meal.—This marine product is prepared from the undecomposed dried waste of the shrimp industry and usually the whole shrimp or the heads and offal. The salt content in the form of common salt (NaCl) must not exceed 7 per cent.

Tankage.—Usually under the name of *digester tankage, feeding tankage,* or *meat meal tankage,* this product is prepared from the residue of animal tissues, except for horn, hoof, manure, and stomach contents in so far as they can be excluded, by tanking under live steam or by dry rendering. It must not contain more than 10 per cent phosphoric acid. If the product contains more bone than the amount equivalent of 22 per cent tricalcium phosphate, it must have the name "Bone" included in the brand name.

Sources of Mineral Supplements.—Most of the cereal grains, vegetable protein supplements, and some of the animal protein supplements are deficient in one or more of the essential mineral nutrients. The table on page 292 gives the distribution of some of the more important minerals contained in various poultry feeds.

The deficiency of certain minerals in cereal grains and grain products is rather easily provided for by feeding animal-protein supplements and comparatively simple mineral mixtures. Calcium, phosphorus, sodium, and chlorine are the minerals most apt to be deficient in the cereal grains and grain products used to make up the poultry diet. On the other hand, when animal-protein supplements are used, there is little need for additional supplies of calcium or phosphorus, except that laying hens require an adequate supply of calcium.

Alfalfa.—The chief value of alfalfa meal or alfalfa-leaf meal from the standpoint of serving as mineral supplements is with respect to their content of calcium.

Bone Meal, Steamed and Special Steamed.—These bone-meal products are relatively high in the content of calcium carbonate and calcium phosphate, the former being used in the formation of eggshell, and the latter in the formation of bone.

TABLE 42.—PER CENT OF SOME IMPORTANT MINERALS IN THE DRY MATTER OF POULTRY FEEDS
(Mitchell and McClure, 1937)

Feed	Ca	P	Na	Cl	Mg	K
Barley	0.075	0.414	0.082	0.173	0.120	0.387
Corn	0.013	0.295	0.021	0.044	0.129	0.368
Oats	0.112	0.434	0.184	0.077	0.130	0.460
Wheat	0.056	0.425	0.035	0.095	0.142	0.590
Wheat bran	0.105	1.260	0.043	0.038	0.562	1.230
Wheat middlings	0.101	1.000	0.114	0.038	0.381	1.120
Cottonseed meal	0.207	1.200	0.046	0.027	0.641	1.570
Alfalfa meal	0.153	0.191				
Bone meal, steamed	31.0	14.4	0.482	0.061	0.808	0.133
Fish meal, herring	4.37	2.85	0.74	0.47	0.21	0.49
Fish meal, sardine	8.34	4.54	0.65	0.42	0.28	0.65
Fish meal, whitefish	6.64	3.46	1.58	1.65	0.22	0.32
Fish meal, codfish	11.9	6.17	1.24	1.12	0.24	0.78
Meat meal	3.30	1.79	1.83	2.69	0.159	0.601
Milk, whole	0.905	0.770	0.524	0.865	0.111	1.09
Milk, skim	1.33	0.980	0.490	0.949	0.146	2.54
Tankage, 50 per cent protein	11.7	5.15				

Ca, calcium; P, phosphorus; Na, sodium; Cl, chlorine; Mg, magnesium; K, potassium.

Clamshells are used to some extent in order to supply calcium carbonate, although they are apparently not quite so satisfactory as oyster shells.

Grass.—Green grass is a good source of iron.

Iodine is the active constituent of the thyroid gland, which has been demonstrated to have a pronounced influence on the physiology of metabolism. It is practically always available in adequate amounts in the normal diet of the chicken and is mentioned here only because certain individuals have attempted to show that the diet should be supplemented with potassium iodide or iodine in some other form.

Limestone is used principally as a source of calcium carbonate, a nonmagnesian limestone, *i.e.*, free of dolomite, being superior to a magnesian limestone.

Meat scraps, although used in poultry feeding primarily as a source of protein, contain considerable quantities of calcium and phosphorus as well as other minerals, so that when meat scraps are used in the diet there need be less concern about any possible deficiency of most minerals.

Milk.—Both whole and skim milk, as compared with the cereal grains, are relatively rich in calcium, phosphorus, sodium, chlorine, and potassium.

Oyster shells contain about 96 per cent of calcium carbonate and are used extensively in feeding hens for the production of the shell of the egg. Oyster shells also contain iodine.

Rock phosphate contains phosphate in the inorganic form but is not a suitable mineral supplement because of its fluorine content, an excess supply of which is harmful both for growth and for egg production.

Salt is used as a source of sodium and chlorine.

Tankage, like meat scraps, is relatively rich in calcium and phosphorus and contains other minerals as well.

Sources of Vitamin Supplements.—Some of the vitamins are rather widely distributed among poultry feeds, although with respect to any one vitamin some feeds have a much higher content than others. Vitamin B, for instance, is present in most poultry feeds, but the cereal grains and their by-products contain much more of this vitamin than practically all other poultry feeds. Likewise, vitamin E is rather widely distributed among the cereal grains, cereal by-products, and forage crops, wheat germ being the richest source. On the other hand, vitamin A is found most abundantly in cod-liver oil, forage crops, some vegetables, and yellow corn, the other cereal grains being deficient in this vitamin. Milk products and liver are the chief source of the growth-promoting fraction of vitamin G. Cod-liver oil is the chief source of vitamin D, practically all of the cereals, cereal by-products, milk, and vegetables being deficient in this important vitamin. The table on page 294 gives the vitamin content of a number of poultry feeds.

From the information given in this interesting table it is apparent that most of the necessary vitamins are rather widely distributed among the various poultry feeds. The one exception is vitamin D, the table indicating that among the various poultry feeds cod-liver oil alone is rich in this vitamin. It should be mentioned, however, that *sardine, pilchard, halibut*, and some other fish oils are also valuable sources of vitamin D. It should also be pointed out that the *ultraviolet rays of sunlight* serve the same function as vitamin D, to a large extent at least. Vitamin D may be developed in the body of a bird that has access to sunlight, the very short wave-length rays of which, known as ultraviolet rays, being responsible for the formation of the vitamin through their action upon certain organic compounds in the skin and body. These ultraviolet rays may be produced artificially by quartz-vapor lamps. The rays of summer are much more effective than those at any other time of the year.

Sources of the antipellagric or filtrate factor of the vitamin G complex are not given in the table, so that it should be noted that the best sources of this vitamin include *milk* and *milk products*.

TABLE 43.—VITAMIN CONTENT OF POULTRY FEEDS AND EGGS
(Norris and Heuser, 1936)

Feeds	Vitamins A	Vitamins B	Vitamins D	Vitamins E	Vitamins G (growth factor)
Cereals:					
Barley	0	++	0	++	+
Buckwheat	0	++	0	−	+
Corn, white	0	+++	0	++	+
Corn, yellow	++	+++	0	++	+
Oats	0	++	0	++	+
Soybeans	−	++	0	−	+
Wheat	0	+++	0	++	+
Cereal by-products:					
Corn-gluten meal	+++	−	0	−	0
Hominy feed	0 to +	+++	0	++	−
Soybean oil meal	−	++	0	−	+
Wheat bran	0	++	0	++	+
Wheat germ	0	++++	0	++++	+
Wheat middlings	0	+++	0	+++	+
Milk products:					
Buttermilk	+	+	0	+	++
Buttermilk, dried	+	+	0	+	+++
Skim milk	0	+	0	+	++
Skim milk, dried	0	+	0	+	+++
Whey, dried	0	+	0	+	+++
Whole milk	++	+	0	+	++
Animal products:					
Cod-liver oil	++++	0	++++	−	0
Fish meal	0 to +	0	0 to +	−	0 to ++
Meat scrap	0	0	0	−	+
Forages:					
Alfalfa, dehydrated	+++	+	0	+++	+++
Alfalfa, green	+++	+	0	+++	++
Alfalfa, sun cured	++	+	+	+++	++
Clover, green	+++	+	0	+++	++
Grasses, green	+++	+	0	+++	++
Vegetables:					
Cabbage, green leaves	++	+	0	−	+
Cabbage, white portion	+	+	0	−	−
Carrots, yellow	+++	+	0	−	−
Mangels	0	0	0	−	−
Potatoes	0	+	0	−	−
Rutabagas	0 to +	+	0	−	−
Tomatoes	++	+	0	−	−
Miscellaneous:					
Eggs	++	+	++	++	+++
Liver, dried	++	+	+	−	++++
Yeast	0	++++	0	0	+++

0 Indicates none or no appreciable amount of vitamin.
+, ++, +++, and ++++ Indicate increasing amount of vitamin.
− Indicates evidence of vitamin content lacking or insufficient.

Sources of vitamin K, the antihemorrhagic vitamin, are *alfalfa* and to a lesser extent *meat scrap* and *fish meal.*

Feeds of Questionable Value.—Some feeds used for poultry do not fall into any of the categories already mentioned but are fed for some other purpose than supplying carbohydrates, fats, proteins, minerals, or vitamins.

Charcoal.—Although charcoal is a good absorbent of gases, the fact has never been established that it serves any useful purpose in the diet.

Grit.—The presence of grit in the gizzard provides for the more efficient grinding of the hard grains than when no grit is supplied. Insoluble grit, rather than limestone grit, is preferable and is obtained usually in the form of crushed quartz, granite, feldspar, and phosphate rock. On the other hand, where all or a large portion of the diet is fed in the form of mash the feeding of grit is perhaps unnecessary.

Roughage Feeds.—Mash mixtures that are very finely ground are apparently not so palatable as less finely ground mixtures and sometimes give rise to an abnormal condition in the beak. On the other hand, especially where whole or cracked grain or normally ground mashes constitute the bulk of the diet, there is no need to add feeds for the express purpose of supplying bulk to the diet. *Hulls, hay, cabbage,* and *silage* are of little value from the standpoint of providing bulkiness; in fact, an excess supply of either bran or hay tends to provide too much fiber in the diet.

Sprouted Grains.—The feeding of sprouted oats and other grains was practiced to a considerable extent a few years ago but has practically ceased. Sprouting appears not to change the feeding value of the grain, and only when alfalfa, grass, or other green feeds are not available would the feeding of sprouted grains with green tops seem to be justified.

Tonics are always of questionable value in poultry feeding, and some of them may be distinctly harmful.

Toxic Feeds.—The poisoning of poultry, especially in large numbers at a given time, is of relatively rare occurrence, although it sometimes occurs in rather serious proportions in individual flocks. In such cases, the trouble is usually due to the fowls' gaining access to poisonous drugs or chemicals or poisonous plants. Since death from poisoning usually occurs before the cause of death is established by diagnosis, and since treatment is rarely practicable, the chief sources of poisoning are mentioned primarily for the purpose of assisting the poultryman to take the necessary precautions to avoid the possibility of mortality from poisoning.

During May and June *rose chafers* may cause excessive mortality from poisoning among chicks about 10 weeks of age. About 20 chafers will kill chickens 1 week old, and about 40 will kill a chicken about 3 weeks old.

In certain sections of South Dakota, corn, wheat, and barley grown on the "alkali" soils characteristic of those sections contain a poisonous element called "selenium" which causes a lowering in the hatchability of eggs and retarded growth in chicks, the latter result occurring when 65 per cent of the grain diet was composed of the affected grain.

The chief sources of drug and chemical poisoning include: (1) *arsenic*, in rat poisons and Paris green; (2) *bichloride of mercury*, the lethal dose being 4 grains for a 4-lb. fowl; (3) *copper sulphate*, sometimes used for medicating drinking water, is toxic when of the strength of 15 grains in solution; (4) *kamala*, sometimes used as a remedy against tapeworms, acts as an irritant in the digestive tract, a dosage of 1 grain per bird resulting in a decline in egg production; (5) *lead*, in paint skins; (6) *nicotine sulphate*, highly poisonous to baby chicks in doses of 2 cc. of a 4 per cent solution; (7) *potassium permanganate*, sometimes used as an antiseptic in drinking water, is poisonous to adult fowls in doses of 30 grains per fowl; (8) *sodium chloride*, or *common salt*, is toxic for chicks and adult fowls in doses of 4 per cent of the live weight.

The more important sources of plant and seed poisoning include: (1) leaves of the *black locust;* (2) *corn-cockle seed*, if consumed in excess of 0.25 per cent of the bird's body weight; (3) *cottonseed meal*, the poisonous principle of which is gossypol, is toxic if fed in very large amounts; (4) the *coyotillo plant* is toxic in doses of 0.3 per cent of the live body weight; (5) *crotalaria seed*, produced by the species *Crotalaria spectabilis*, which is grown in some southern states as a legume; (6) *daubentonia seed*, from an ornamental shrub grown in the Gulf states; (7) *milkweed*, sometimes eaten by poultry when other green plant material is not available; (8) the *nightshade plant and berries;* (9) the green sprouts of potatoes; (10) tobacco, sometimes added to mashes as a vermifuge, is toxic in its effects in excessive amounts. The Pennsylvania Agricultural Experiment Station found that cigar-leaf tobacco containing 0.86 per cent nicotine caused excessive mortality among chicks during the third and later weeks when their mash contained as much as 0.06 per cent nicotine.

MIXING FEEDS FOR A BALANCED DIET

Growing chicks and laying hens will do quite well on a comparatively simple diet provided they have access to sunlight and also have access to a range where young grass is always available. Under other conditions, such as when the birds are confined to houses because the ground is frozen or covered with snow, and especially when rapid growth or high egg production is desired, the diets should be comprised of a variety of feeds to make sure that the nutrients are properly balanced. When birds are kept in strict confinement without access to sunlight, the proper balancing of the nutrients is very important to make up for the absence of the ultra-

violet rays of sunlight and the proteins, minerals, and vitamins that are secured from the growing green crops and from the soil.

Because there are so many different nutrients needed for growth and egg production as well as for other purposes and because some of the different nutrients produce entirely different effects, it is clear that the proper balancing of the nutrients is an extremely complicated problem. Moreover, existing knowledge is in a rather fragmentary state concerning the nutritive value of all of the nutrients that each kind of feed contains and the optimum requirements of all nutrients for any particular purpose. Research workers sometimes refer to certain diets being tested as "adequate," whereas, as a matter of fact, only the final results secured can determine whether or not a particular diet proved adequate, and even then it is possible that a slight modification might have given still better results.

For many years the nutritive ratio was considered to be of considerable importance in the preparation of diets, the ratio being based upon the proportion of digestible carbohydrate and fat (estimated as carbohydrate) to one part digestible crude protein. The nutritive ratio does not take into consideration the mineral elements in the diet, nor does it take cognizance of the vitamins. Moreover, as far as the digestible protein portion of the diet is concerned, it does not take into account the fact that the various amino acids serve different purposes, some of them being unable to replace others. The newer knowledge of poultry nutrition has obliterated any usefulness the nutritive ratio may perhaps have served.

Nevertheless, the proper balancing of the nutrients in a diet is of great importance if the most satisfactory results in any direction are to be obtained. Enough is known of the specific effects of some of the nutrients contained in various feeds to suggest that a diet serving as the sole source of nourishment for a chicken can be balanced only when it contains nutrients from several different feeds. During the past several years numerous experimental feeding tests have been carried on for the purpose of comparing the relative value of different feeds and different combinations of feeds for different purposes. A brief statement of the general results obtained from these feeding tests will perhaps suffice to indicate the manner in which the balancing of a diet for particular purposes can be achieved.

Relative Value of Cereal Grains.—Corn, wheat, oats, and barley or combinations of two or more of these grains and their by-products are the ones most frequently used to supply the major portion of practically all poultry diets. In a very general sense they have approximately the same feeding value for chicks, fattening stock, and laying birds.

Although it is true that these four cereal grains appear to have comparable nutritive values, it is also true that they differ in certain outstand-

ing respects. With the exception of yellow corn, all are deficient in vitamin A. The fiber content of barley and oats is liable to be excessively high unless heavy-weight grains are used. There is sometimes more difference between the nutritional value of two lots of barley or two lots of oats than between barley and any of the other three grains or between oats and any of the other three grains. When oats are used they should be rolled coarsely, not ground.

Experiments conducted with rye at the Wisconsin and Wyoming agricultural experiment stations seem to indicate that this cereal grain should not comprise more than about 15 per cent of the diet of growing chicks or laying hens. Moreover, rye is not palatable.

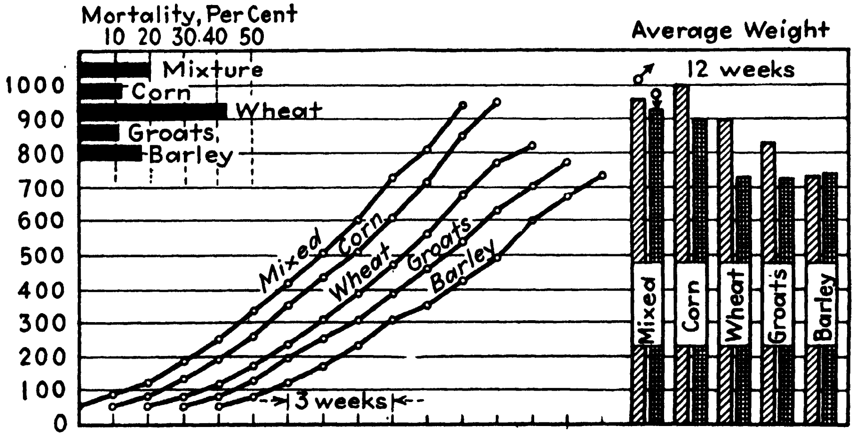


FIG. 135.—Showing the influence on growth, average weight, and mortality in Barred Plymouth Rock chicks fed single-cereal diets compared with a mixed-cereal diet, all diets being supplemented with buttermilk and meat scraps. (*Branion*, 1933.)

Buckwheat may be used to some extent in fattening diets.

Some of the sorghums, such as kafir and milo, can replace yellow corn, according to work done at the Kansas Agricultural Experiment Station, provided they are properly supplemented with other nutrients.

In the previous chapter it has been pointed out that the proteins of all cereal grains are deficient in certain amino acids and need to be supplemented with proteins from other sources, especially animal feeds. The cereal grains also need to be supplemented with certain minerals and vitamins.

The relative efficiency of the cereal grains seems to depend upon the kind of supplements that are added to each of the grains. For instance, in indoor feeding tests conducted at the Ontario Agricultural College with Barred Plymouth Rock chicks up to 12 weeks of age it was found that ground yellow corn promoted better growth than ground wheat, barley, or oat groats, each diet being made up in the proportions of the following number of pounds of feed: the particular cereal, 100; powdered butter-

milk, 10; fish meal, 7; alfalfa-leaf meal, 5; oyster shell, 2; bone meal, 1; iodized salt, 0.5; and 1 pt. of cod-liver oil. It was also found that a mixed-cereal diet of equal parts of corn, wheat, barley, and oat groats gave better results than any of the single-grain diets, with the exception of corn. On the other hand, the corn diet produced by far the highest percentage of deformed legs. The feathering of the cockerels and pullets at 12 weeks of age was the poorest on the wheat diet; next poorest on the oat-groats diet; the corn, barley, and mixed-cereal diets being comparable.

In another feeding test conducted at the Ontario Agricultural College with Barred Plymouth Rock chicks up to 12 weeks of age it was found that the relative standing of the four cereal grains differed depending upon whether the single protein supplement used was powdered buttermilk to the extent of 25 per cent of the diet, fish meal to the extent of 12 per cent of the diet, or meat meal to the extent of 16 per cent of the diet. In all three cases the crude-protein content of the protein supplements was approximately the same. The weights of the chicks at the conclusion of the test are given in the accompanying table.

TABLE 44.—WEIGHTS IN GRAMS AT 12 WEEKS OF AGE IN BARRED PLYMOUTH ROCK CHICKS FED SINGLE CEREAL GRAINS, EACH SUPPLEMENTED WITH THREE DIFFERENT SINGLE PROTEIN FEEDS OF ANIMAL ORIGIN
(Branion, 1934)

Cereal grain	Protein supplement		
	Powdered buttermilk	Fish meal	Meat meal
Corn	885	760	487
Wheat	814	752	586
Oat groats	845	833	705
Barley	755	761	722

The data in the table show that when powdered buttermilk was used as the protein supplement, the relative standing of the four cereals was corn, oat groats, wheat, and barley. When fish meal was used, the relative standing was oat groats, barley, corn, and wheat. When meat meal was used, the relative standing was barley, oat groats, wheat, and corn. The best growth was made by corn supplemented with powdered buttermilk, and the poorest was made by corn supplemented with meat meal.

Although it is true that in many respects the four cereal grains, corn, wheat, oats, and barley, may replace each other in poultry diets, it is also true that a mixture of the four will usually give better results. This

is apparently because the cereal grains differ in the quality of their proteins, a combination tending to give a better balance.

Relative Value of Protein Supplements.—Since the feeds used as sources of protein supplements are relatively the most expensive part of the diet, it is very important that the proper kinds and proportions be added to the diet in order to secure the most efficient results in feeding.

The results of a large number of feeding tests carried on at various institutions over a period of years indicate clearly that protein supplements of animal origin are for the most part superior to protein supplements of plant origin. The superiority is due not only to differences in the quality of the proteins but also to the fact that animal-protein feeds contain certain minerals and vitamins that are lacking in plant feeds used as sources of supplementary protein. The results of the various experiments are briefly summarized here with a view toward giving a general picture of the problem concerning the relative value of protein supplements.

Protein Supplements for Growth.—In the preceding chapter it was pointed out that rate of growth is determined to a large extent not only by the amount of feed consumed but also by the quality and level of the protein content of the diet. Some very interesting results have been secured concerning the relative value of protein supplements of plant and animal origin in experiments designed to make comparisons possible.

Experimental work conducted at the Nebraska Agricultural Experiment Station led to the conclusion that the nutritive value of various protein supplements added to a corn-wheat basal diet could be expressed in the following terms, the letters AA designating the highest, and D the lowest quality:

Dried buttermilk	AA	Blood meal	B
Fish meal	AA	Cottonseed meal	B
Casein	AA	Linseed-oil meal	C
Meat and bone meal	A	Corn-gluten meal	C
Soybean meal	A	Gelatin	D

The results secured from an extensive series of experiments at Cornell University are typical, in many respects, of results secured at other institutions, and since the Cornell results have been stated in terms of the relative efficiency of the different protein supplements tested they are given in Table 45.

Inasmuch as dried skim milk was observed to possess the same protein efficiency as casein, it would seem that the deficiency of cystine in casein was supplied in adequate amounts by the cereal grains used in the diet.

The differences in the protein efficiency of the various fish meals tested are due not only to the different parts of the fish that are used in

the different meals but also to the process of manufacture. The proteins of white fish meals, consisting chiefly of backs and heads, proved to be superior to the milk proteins. Vacuum and steam-dried white fish meals proved to be significantly superior to flame-dried white fish meals. The sardine fish meals tested were prepared by being wet rendered and then dried in indirect flame. It was observed that menhaden fish meals

TABLE 45.—RELATIVE PROTEIN EFFICIENCY OF PROTEIN SUPPLEMENTS
(Wilgus, Norris, and Heuser, 1935)

Protein Supplement	Relative Protein Efficiency
Casein	100
Dried skim milk	100
White fish meal:	
Vacuum dried	104
Steam dried	104
Flame dried	94
Sardine fish meal:	
Domestic	98
Asiatic	91
Menhaden fish meal:	
Steam dried	91
Flame dried	80
Soybean meal:	
Expeller process	89
Hydraulic process	85
Meat scrap:	
75 per cent protein	69
60 per cent protein	75
55 per cent protein	82
50 per cent protein	73
45 per cent protein	72
Whale-meat meal:	
70 to 75 per cent protein	73
55 to 60 per cent protein	53
Corn-gluten meal	61
Ground soybeans	58

produced by the flame-drying process were, in general, inferior in protein efficiency to those produced by the steam-drying process.

The results secured with expeller-process and hydraulic-process soybean meals were not markedly different. Work at the Wisconsin Agricultural Experiment Station showed that soybean meals prepared by the high-temperature expeller process, medium- and high-temperature hydraulic processes, and solvent-extracted process were superior to soybean meals produced by the low-temperature expeller process and to raw soybeans.

The Cornell results with meat scraps indicate that the rendering process employed does not markedly affect their protein efficiency. The relatively low protein-efficiency value of the 75 per cent protein sample was attributed to the fact that it contained pork cracklings. At the California Agricultural Experiment Station it was found that vacuum-dried beef and whale-meat meal were superior to meat scraps, the latter being considerably superior to tankage. As the result of experiments conducted at the Larrow Research Poultry Farm it was concluded that meat scraps high in free fatty acids decrease the feed consumption and rate of growth in chicks. The research workers carrying on the work have suggested that these effects are not due to the fatty acids themselves but to the inactivation of vitamin A and, to a lesser degree, of vitamin D in the diet.

Although corn-gluten meal was found by the Cornell workers to have a low protein-efficiency value, other work has shown that its proteins can be increased in value when properly supplemented. The value of supplementing the proteins of plant origin is borne out by the results secured at the Wisconsin Agricultural Experiment Station with soybean-oil meal. A diet supplemented with 12 parts soybean-oil meal, 2 parts meat scraps, and 2 parts dried milk plus minerals proved to be superior to a diet supplemented with 16 parts soybean-oil meal plus minerals.

The results secured from a number of widely scattered experiments indicate that the growth-promoting properties of a diet are enhanced when it is supplemented with a mixture of such animal proteins as milk, good-quality meat scraps, and vacuum-dried fish meals.

Protein Supplements for Market-egg Production.—The results that have been secured in determining the best sources of protein supplements for growing chicks have also been found to apply for the most part in the feeding of the laying stock. Not only must protein supplements be added to the cereal grain, but at least a portion of the protein supplements should be of animal origin. Vegetable-protein concentrates have generally been found to be deficient for maximum egg production, although they can be used to good advantage along with animal-protein supplements, thereby sometimes effecting a reduction in the cost of the diet. Young green cereal grass is relatively rich in protein and may be used to good advantage in many diets.

Somewhat typical of the results secured from a wide variety of feeding tests on the effect of the quality of various animal-protein supplements on egg production are the results secured from an experiment conducted at the National Agricultural Research Center. The basal feed mixture used consisted of the following parts by weight: ground yellow corn, 500; wheat bran, 245; rolled oats, 150; and alfalfa-leaf meal, 55; sufficient amounts of ground limestone and steamed bone meal were added so that each diet

contained approximately 3.0 per cent of total calcium and 1.2 per cent of total phosphorus. The protein supplements tested included the following: (1) a mixture consisting of 40 per cent of a specially prepared desiccated-meat meal, 35 per cent of white fish meal, and 25 per cent of dried buttermilk; (2) ground dried lean meat; (3) all-beef scrap, such as is made for commercial purposes but containing no added high-protein materials such as blood meal and stick; (4) meat-and-bone meal, analyzing 55 per cent protein and containing about 20 per cent blood meal; (5) meat-and-bone meal containing no added blood meal or stick; (6) blood meal and stick. Each diet tested contained 20 parts of one of the foregoing protein supplements per 100 parts of the total diet. The egg-production results secured are given in the accompanying table. The feeding tests were carried on for approximately one year.

TABLE 46.—PER CENT EGG PRODUCTION ON DIETS CONTAINING DIFFERENT ANIMAL-PROTEIN SUPPLEMENTS
(Titus, Byerly, Ellis, and Nestler, 1936)

Protein supplement	Protein content of		Per cent egg production
	Protein supplement	Diet	
None		11.8	19.8
Meat, fish, milk	58.8	20.9	23.1
Ground, dried, lean meat	61.3	21.5	29.2
All-beef scrap	50.0	21.4	25.2
Meat-and-bone meal, 55 per cent protein	55.2	20.4	23.8
Meat-and-bone meal, no blood meal or stick	48.3	19.5	24.8
Blood meal and stick	80.0	24.4	26.7

The data given in the table show that the various packing-house by-products tested supported reasonably good egg production, being somewhat more efficient than the meat-fish-milk combination. The results of other experiments indicated that the materials used in making meat scrap and similar products are of relatively greater importance in determining their nutritive value than the temperature and length of time in processing, provided the temperature does not exceed 200°F. or the processing time 8 hr. It was suggested that a packing-house by-product to be of superior quality should be made up of the various parts of the animal in the following proportions: carcasses, 20; beef rennets, 15; hashed pecks, 15; skulls, 10; spleen, 10; livers, 10; tripe trimmings, 10; and beef-cutting scrap, 10.

At the Washington Agricultural Experiment Station feeding tests were conducted with Alaska-herring fish meal, a 62 per cent meat scrap, spray-process-dried skim milk, and a Manchurian soybean-oil meal. The basal

mixture was composed of the following parts by weight: ground yellow corn, 20; millrun, 18; ground heavy oats, 15; ground barley, 15; ground white wheat, 15; wheat middlings, 10; dehydrated alfalfa, 7. Oyster-shell flour and bone meal were used to supply the calcium and phosphorus. Each diet contained approximately 16.0 per cent protein, 2.3 per cent calcium, and 0.9 per cent phosphorus. Fish meal as (1) a protein supplement was tested against the following combinations: (2) fish and soybean-oil meal; (3) fish and dried skim milk; (4) fish and meat scrap; (5) fish, meat scrap, and dried skim milk; (6) dried skim milk and meat scrap; (7) meat scrap and soybean-oil meal; (8) dried skim milk and soybean-oil meal. The per cent egg production was as follows: 53.6, 57.1, 53.6, 52.5, 51.6, 51.5, 49.5, 55.1. The differences in egg production were not significant, revealing the fact that if the diet contains at least one high-quality protein supplement of animal origin, satisfactory egg production may be obtained, provided the diet is otherwise properly balanced.

An illustration of the need of a proper balance of proteins in the diet for egg production is revealed in the results of feeding tests carried on at the Ontario Agricultural College. The control diet for a basis of comparison with single cereal grains consisted of a mixture of equal parts corn, wheat, oat groats, and barley. The other diets consisted of each of these four grains fed singly. To each of the five diets was added a mixed animal-protein supplement consisting of 10 parts powdered milk and 7 parts fish meal. In addition, each pen of birds was supplied with alfalfa, cod-liver oil, bone meal, oyster shell, and grit in separate hoppers. The average egg production per hen per month was as follows: cereal mixture, 14.6; wheat, 10.2; corn, 9.8; barley, 9.6; and oat groats, 6.6. These results indicate that different cereals require different combinations of animal proteins to balance the diet properly. When a mixture of cereal grains is used in making up the diet for egg production, which is the case with practically all poultry diets in common use, it has been found that a factor of safety in the proper balancing of the animal-protein supplements is provided by using milk in some form and fish meal and meat scraps that are high in protein quality.

The diet of molting hens should be as well balanced as possible with respect to proteins in order to promote feather growth, a relatively high level of protein serving to stimulate increased feed consumption, which in turn tends to maintain good body weight.

Protein Supplements for Hatching-egg Production.—Diets for the production of good hatching eggs may be the same as those for good market-egg production, with certain important exceptions. In the experiment conducted at the National Agricultural Research Center, mentioned previously, it was found that the hatchability of eggs was reduced when the diet contained blood meal and stick, embryonic mor-

tality being relatively high throughout the period of incubation and especially during the third week. In other experiments conducted at the same institution it was found that soybean meal made from the Mammoth Yellow variety gave very poor hatchability and that expeller-process soybean meal made from the Illini variety gave very low winter hatchability, the diet containing approximately 20 per cent of the soybean meal. The same percentage of cottonseed meal in the diet increased the incidence of an embryo abnormality called "chondrodystrophy" and gave low hatchability. On the other hand, young green cereal grasses are noted for the high quality of protein that they possess and serve in balancing the protein portion of the diet.

In the experiment at the Washington Agricultural Experiment Station mentioned previously, it was observed that hatchability was higher in the case of all combinations of protein supplements containing milk than in diets not containing milk. It is probable, of course, that the presence of the riboflavin vitamin in milk was responsible for some of the increase in hatchability, although milk is known to contain proteins of high quality.

In an experiment conducted at the Ontario Agricultural College it was found that ribbon milk, powdered milk, semisolid milk, and liquid skim milk each gave equally satisfactory results in hatchability when added to a grain mixture of equal parts by weight of crushed oats, wheat, and barley.

At the same institution it was found that the addition of liver or liver extract to diets containing other animal proteins except milk improved hatchability by decreasing embryonic mortality, especially during the first, second, and third peaks of embryonic mortality which were found to be characteristic in the case of the control, meat-meal, and fish-meal supplemented diets tested. Liver meal contains proteins of high quality and is also rich in the riboflavin vitamin that has been found to be of considerable importance in embryo development and hatchability.

Balancing the Diet with Mineral Supplements.—Among the various minerals required for growth and egg production, practically all, in so far as known, are supplied in sufficient quantities in the cereal grains and animal-protein supplements usually used in the preparation of diets. The cereal grains and their by-products, however, are quite deficient in calcium. Diets containing the proper amounts of animal-protein supplements may have sufficient calcium for growing chicks but not for laying hens.

When vegetable-protein supplements, such as soybean meal and cottonseed meal, replace all or part of the animal-protein supplements, the calcium deficiency incurred may be compensated for by adding steamed bone meal or nondolomitic limestone. For each 5 lb. of vegetable-pro-

tein supplement replaced, approximately 1 lb. of steamed bone meal or a mixture of steamed bone meal and limestone should be added to the diet.

Alfalfa is relatively rich in calcium and helps to balance the diet with respect to this mineral. The minerals contained in young green

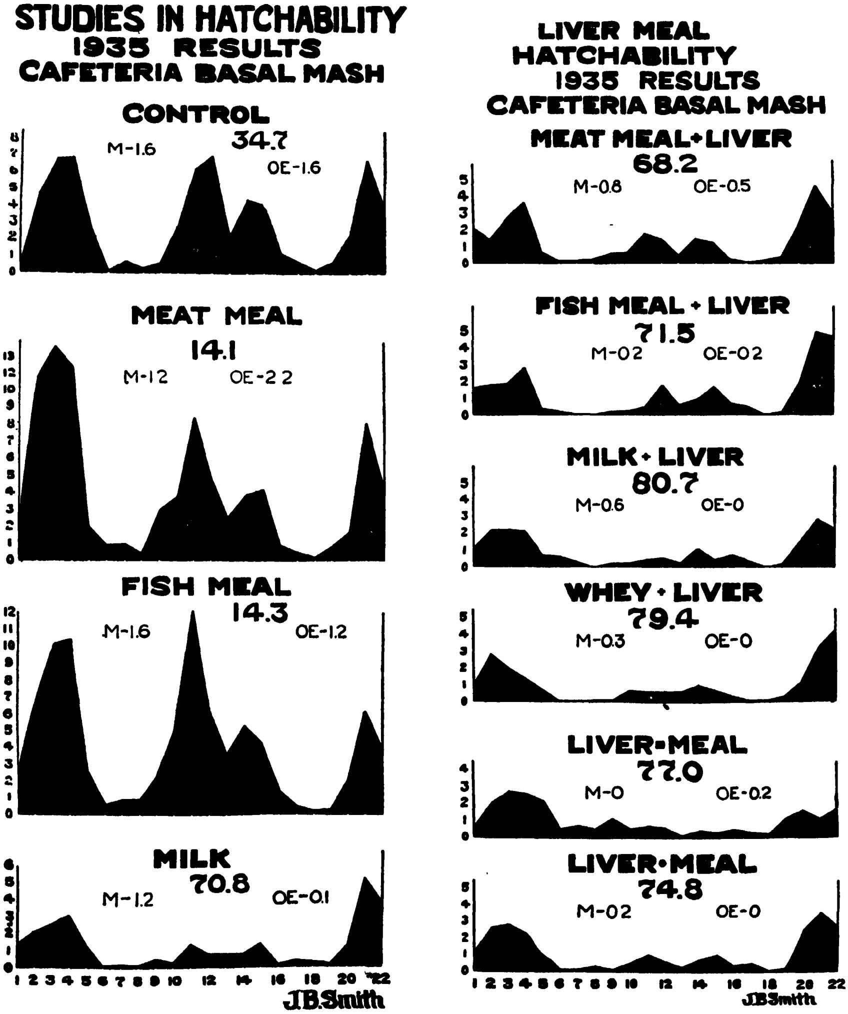


FIG. 136.—Showing the effect of liver meal in reducing the first, second, third, and to some extent the last peak in embryo mortality. Increased hatchability occurred in all trials irrespective of the efficiency of the other animal protein supplements used in the diet. Liver meal either greatly reduced or eliminated teratological monsters or malformations (*M*) as well as oedema, a diseased condition (*OE*). (*Smith and Branion*, 1936).

cereal grasses are of value in balancing the diet. Wheat gray shorts have been found by the Texas Agricultural Experiment Station to contain a mineral that tends to prevent the development of perosis in growing chicks.

For satisfactory egg production the calcium requirement is so intense that calcium supplements must be added even to a diet relatively rich in animal-protein supplements. The supplements usually used are oyster shells, mussel shell, calcite, or other satisfactory sources of calcium carbonate, the form of calcium apparently best suited for the production of market and hatching eggs. Calcium supplements are usually fed in self-feeding hoppers.

A point of particular importance with respect to providing calcium supplements is that the calcium content of the diet should bear a fairly definite ratio to the phosphorus content, as explained in the previous chapter.

Common salt is frequently added to the diet to supply sodium and chlorine.

There is some indication that manganese should be added in very small amounts to the diet for growth and for the production of market and hatching eggs, apparently one-fifth of a pound of manganese sulfate per ton of feed being sufficient.

Balancing the Diet with Vitamin Supplements.—In spite of the fact that research work has already demonstrated that several vitamins are necessary for growth and egg production as well as to promote the physiological well-being of the chicken, it is probably true that many of the vitamins are supplied in abundance in most of the commonly used diets when chickens are exposed to a reasonable amount of sunlight and have access to a good range of young grass. It is when chickens are confined, without access to sunlight and a good range of young grass, that special attention must be given to the proper balancing of the diets by the addition of feeds rich in certain vitamins. Chicks raised in batteries and laying hens kept in batteries require very carefully balanced diets. In many sections of the country where snow covers the ground or where the weather is cold during the winter months, the laying and breeding stock is usually confined, and, being deprived of access to sunlight and grass range, may be fed diets that are deficient with respect to certain vitamins.

Young green grass, alfalfa, kale, yellow carrots, and certain other feeds are good sources of carotene from which vitamin A is formed. In yellow corn the source of vitamin A is cryptoxanthin. Alfalfa-leaf meal is usually a better source than alfalfa meal, but both kinds of feed show great variability with respect to their vitamin A potency, especially sun-cured products. Cod liver also contains vitamin A. In all feeds exposed to the air, the vitamin A potency decreases considerably.

Since vitamin B is found in the outer covering and germ of grains and in alfalfa, young grass, and milk, there is little likelihood of additional amounts being required in the ordinary diet.

Vitamin D must be added to the diet for chicks reared in confinement or early in the season before the ultraviolet rays of sunshine are sufficiently effective to prevent rickets. Cod-liver oil is the most common form used to supplement the diet with vitamin D, although recent research has demonstrated that white sea-bass liver is about 2.6 times as effective as cod-liver oil, and dogfish-liver oil has also been found to be more potent. Sardine-liver oil has practically the same potency as cod-liver oil, and halibut-liver oil is slightly less potent than cod-liver oil. There are two

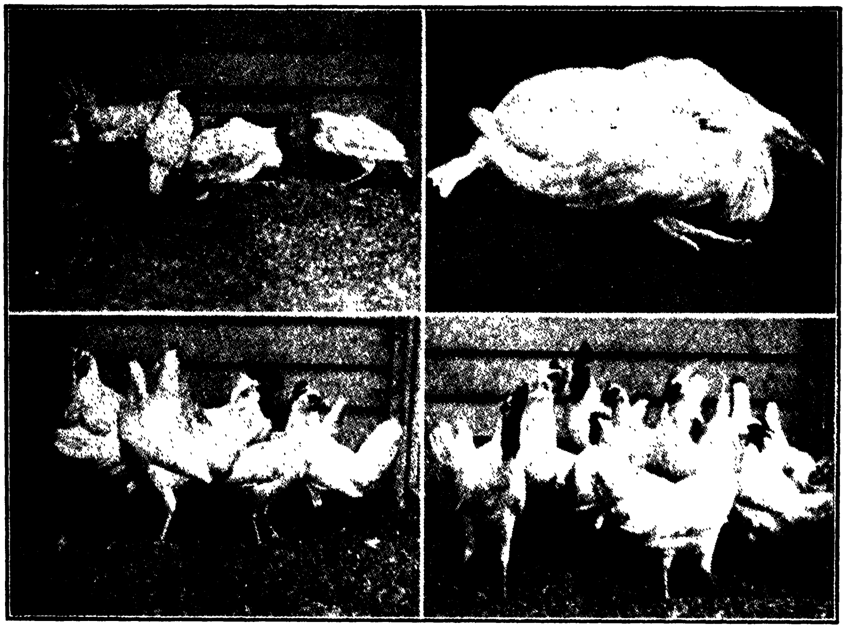


FIG. 137.—Vitamin A is necessary for chicks. Upper left, Lot 1, received no yellow corn in their diet. Upper right, individual from Lot 1; note the condition of the eye Lower left, Lot 2, received 25 per cent yellow corn in the diet. Lower right, Lot 3, received 50 per cent yellow corn in the diet. All chicks photographed at 17 weeks of age. (*Hauge, Carrick, and Prange*, 1927.)

or more forms of vitamin D in fish oils, the proportions varying in different oils.

Investigational work has demonstrated that some commercial cod-liver oils have been relatively high in free fatty-acid content, which is objectionable from the standpoint of sometimes retarding growth and causing high mortality.

For the production of market and hatching eggs by birds kept in confinement, their diet should be supplemented with vitamin D. Cod-liver oil has been shown to be a more efficient source of vitamin D than irradiated ergosterol or the irradiation of the birds.

An addition of vitamin D to the diet of breeding stock at certain seasons of the year for the production of eggs of good hatchability is

clearly indicated by results secured at the Ontario Agricultural College over a period of 3 years. The effect of the ultraviolet rays of sunshine in promoting proper bone calcification is approximately eight times as great from April to August as from November to January. In Ontario the

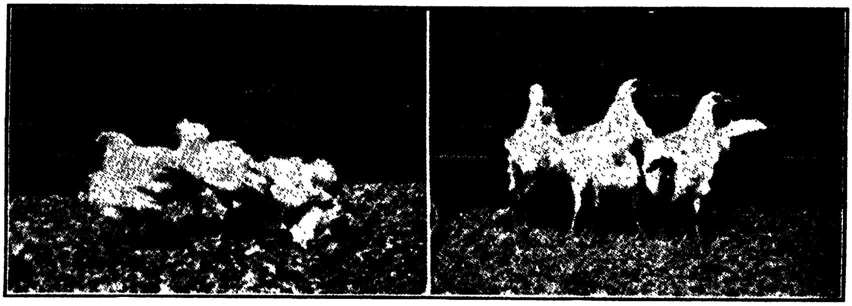


FIG. 138.—The effect of exposing chicks afflicted with leg weakness to 15 minutes' direct sunlight, daily, for 4 weeks. Left, before exposure. Right, after exposure. (*Bethke and Kennard*, 1927).

amount of sunshine in February is approximately one-third of the amount in July, and it has been found that from February to July the hatchability of eggs increased in almost direct proportion to the increase in the amount of sunshine from month to month.

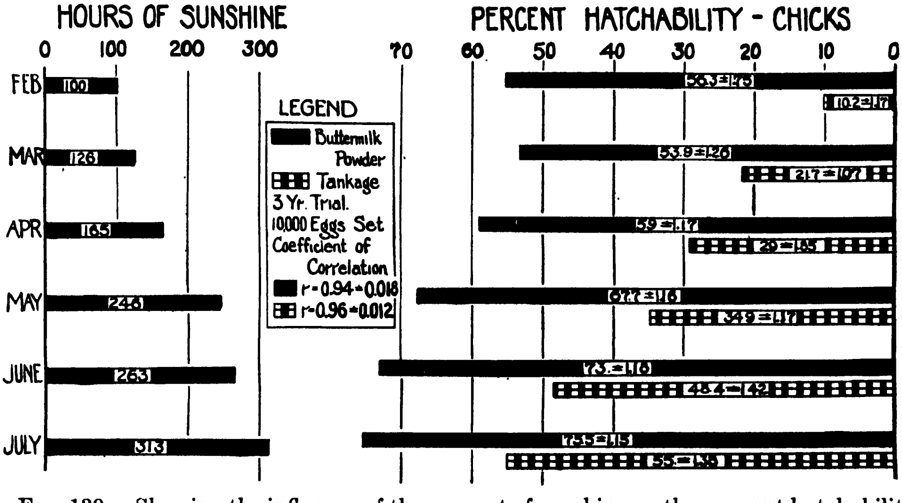


FIG. 139.—Showing the influence of the amount of sunshine on the per cent hatchability when two sources of animal protein, differing widely in their feeding value, were used in the diet. (*Smith*, 1934.)

In numerous experiments carried on at different institutions it has been demonstrated that cod-liver oil is a valuable source of vitamin D for the purpose of making up for the deficiency of sunshine, at least to a considerable extent. Some work has been done, however, the results of which indicate that sunshine contains some factor other than vitamin

D that effects an improvement in hatchability. For instance, at the National Agricultural Research Center it was observed that the hatchability of the eggs produced by birds fed Illini-soybean meal as part of their diet was improved by direct sunlight through some mechanism other than vitamin D.

Since liver oils are purchased by poultry raisers primarily as a source of vitamin D for supplementing the diet, it is very important for the purchaser to know the potency or U.S.P. units per gram of the oil. The following statement, prepared by the Pennsylvania Agricultural Experiment station, gives the quantities of oils of various potencies that are required to supply the optimum amounts of vitamin D in diets for growing chicks and laying and breeding stock:

Vitamin D potency[1] of oil, U.S.P. units per gram	No. of U.S.P.[2] units per pound of oil	No. of U.S.P.[3] units required in 100 lb. of mash	Approximate per cent[4] of oil to be added to the mash	Approximate pounds of oil to be added to 1 ton of mash
When an all-mash ration is fed to growing chicks				
50	22,700	17,700	0.78 or ¾	15
85	38,590	17,700	0.46 or ½	10
310	140,740	17,700	0.13 or ⅛	2½
400	181,600	17,700	0.10 or 1 to 10	2
When a grain and mash ration (equal parts) is fed to growing chicks or an all-mash ration is fed to laying hens				
50	22,700	35,400	1.56 or 1½	30
85	38,590	35,400	0.92 or 1	20
310	140,740	35,400	0.25 or ¼	5
400	181,600	35,400	0.19 or 1 to 5	4
When a grain and mash ration (equal parts) is fed to laying and breeding hens				
50	22,700	70,800	3.12 or 3	60
85	38,590	70,800	1.83 or 2	40
310	140,740	70,800	0.50 or ½	10
400	181,600	70,800	0.39 or 2 to 5	8

[1] In simple terms a U.S.P. unit is a measuring stick used in expressing the potency of a vitamin D substance in terms of a reference standard.

[2] The number of U.S.P. units per pound of oil is obtained by multiplying the number of U.S.P. units per gram of oil by 454 (the number of grams in 1 lb.).

[3] These recommendations are the results of an extensive 4-year study on vitamin D requirements of chickens.

[4] The approximate per cent of oil to be added to the mash is obtained by dividing the number of U.S.P. units required per 100 lb. of mash by the number of U.S.P. units per pound of oil.

Since the requirements of the riboflavin vitamin are relatively large in the case of both promoting growth and producing eggs of high hatch-

ability, the diets for growing chicks and breeding stock should contain adequate amounts of feeds rich in this vitamin. Cornell University

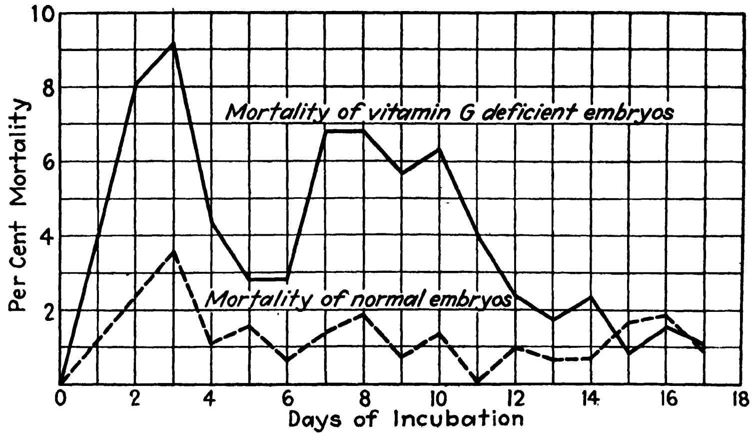


FIG. 140.—Showing the influence of riboflavin (vitamin G) upon embryonic mortality. (*Davis, Norris, and Heuser*, 1938.)

research workers have compiled the following table showing the relative riboflavin content of various protein supplements, the value of dried pork liver being designated as 100.

TABLE 47.—RELATIVE AMOUNTS OF THE RIBOFLAVIN VITAMIN IN VARIOUS PROTEIN SUPPLEMENTS

(Wilgus, Norris, and Heuser, 1935)

Protein Supplement	
Dried pork liver	100
Dried skim milk	19
White fish meal:	
Vacuum dried	10
Steam dried	5
Flame dried	5
Sardine fish meal:	
Domestic	9
Asiatic	5
Menhaden fish meal:	
Steam dried	5
Flame dried	4
Soybean meal:	
Expeller process	4
Hydraulic process	3
Meat scrap:	
75 per cent protein	6
60 per cent protein	7
55 per cent protein	5
50 per cent protein	6
45 per cent protein	6
Corn-gluten meal	0
Dried blood	0
Ground soybeans	3

Observations made at the Washington Agricultural Experiment Station indicate, however, that the values given in this table may be somewhat high because of the fact that the basal diet was not always adequate in the filtrate factor vitamin, which also promotes growth. At the same institution it was observed that dried whey contains from between 10 to 20 per cent more riboflavin than dried skim milk. Work at Cornell University has shown that sun-cured alfalfa meals contain 60 per cent as much riboflavin as dried skim milk.

Since it has been pointed out in the previous chapter that the vitamin called "filtrate factor" is necessary to induce optimum growth in chicks, it is worth while giving here the contents of this factor in units per gram of the following feeds, as found by the California Agricultural Experiment Station: cane molasses, 6.0; dried skim milk, 3.0; dehydrated alfalfa-leaf meal, 3.0; alfalfa-leaf meal, 1.3; and dried young alfalfa shoots, 1.0.

The three vitamins, E, the gizzard-factor vitamin, and the antihemorrhagic vitamin are not likely to be deficient in any normal poultry diet.

THE ESSENTIALS OF A WELL-BALANCED DIET

From what has been said previously in this chapter, it is perfectly apparent that in order to give the most satisfactory result for any particular purpose a diet must be properly balanced with respect to the various nutrients that it contains. Not only must the various nutrients be of good quality, as in the case of the proteins, but they must be in proper proportions, as in the case of the calcium and phosphorus portions of the diet.

A well-balanced diet is considered to be one that is made up of the right kinds of feeds combined in such proportions so as to produce the desired results as efficiently as possible. In broiler production, for instance, it is not so much a matter of how fast the chicks can be made to grow as how efficiently can gain in weight be obtained on the basis of the feed consumed and such other factors as the number of birds that die because of faulty nutrition and the quality and condition of the fleshing of those that live to be marketed. So with respect to feeding for egg production, a well-balanced diet is one that promotes efficient egg production on the basis of feed consumption and ensures the largest possible number of birds' being alive and in good condition at the end of the laying period.

Diet Properly Balanced for a Particular Purpose.—The purpose for which a diet is intended makes a difference as to just how it should be balanced. A diet for breeding stock should have relatively less protein, more calcium and phosphorus, much more vitamin A and vitamin D, and perhaps a little less of the riboflavin vitamin than a diet for broilers.

Birds in confinement need to have a much more carefully balanced diet than those that are allowed in the sunlight and have access to a good range of young grass. These are but two examples of the thought that must be given to the proper balancing of the diet for the purpose intended. It should be added, of course, that the nature of the diet fed is of great importance from the standpoint of the quality of the product produced. The calcification of bone, the quality of flesh, the color of the yolk, the hardness of the shell, the condition of the thick and thin white, and the hatchability of the eggs are factors that should be kept in mind in balancing the diet.

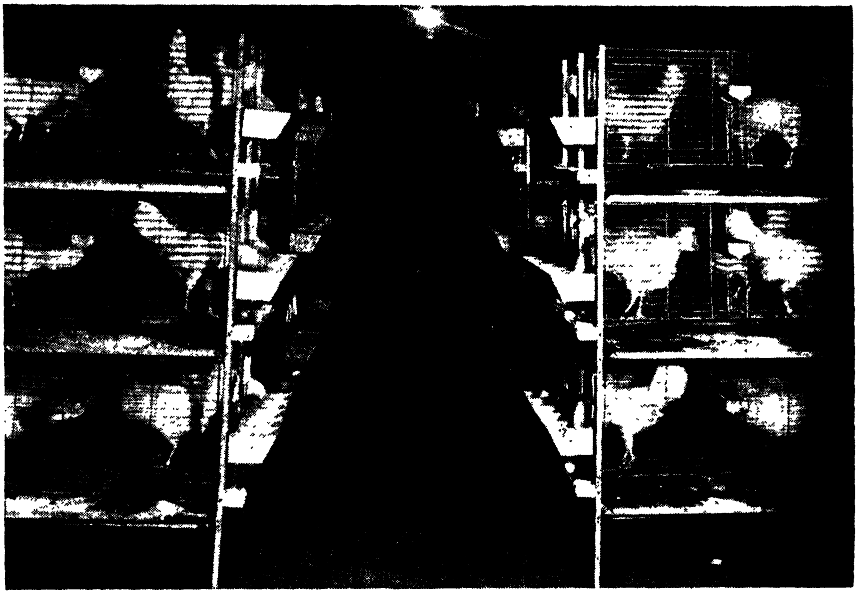


Fig. 141.—Layers kept in batteries or laying cages require much more carefully balanced diets than layers given access to range. (*Winter*, 1937.)

In order to be able to balance diets most wisely for any particular purpose, the poultryman must have an adequate knowledge of the nutritive requirements of different classes of chickens and of the effects of various combinations of the necessary nutrients. In other words, the most successful feeder is one who knows the chickens' needs and the possibilities of the various feeds.

Palatability of Feed Important.—The consumption of feed by chickens seems to be dictated largely by the senses of sight and touch rather than by smell and taste. Palatability implies, therefore, attractiveness and satisfaction in the eating thereof. Rolled oats are preferred to ground or crushed oats. Mashes composed of very finely ground grains are not so palatable as those composed of more coarsely ground grains. The feeding of a very finely ground all-mash diet to chicks sometimes gives rise to a

condition known as "necrosis of the beak." Some of the finely ground feed adheres to the beak and remains under the tongue, causing discomfort and reducing feed consumption. The feeding of fresh mashes will stimulate increased feed consumption over that of stale mashes.

A Certain Degree of Bulkiness Desirable.—From what has just been said about the undesirability of the excessively fine grinding of grains, it follows that the mash portion of the diet should have a certain amount of bulkiness. Chickens apparently have a limited capacity for digesting fiber, although the Oklahoma Agricultural Experiment Station has shown that diets containing about 3 to 10 per cent fiber gave equally satisfactory results. A certain amount of bulkiness apparently aids in the more complete digestion of the nutrients in their passage through the digestive tract.

Maintaining Physiological Well-being.—The chicken is, in reality, a physiological machine which is fed the raw materials from which it is expected to produce flesh or eggs in abundance. The physiological processes that are involved in transforming raw materials into finished product entail a heavy strain upon the digestive and other systems. The demand for more rapid growth in broiler production and for higher egg production in the laying stocks requires that special consideration be given to the requirements of the chicken, particularly with respect to the proteins, minerals, and vitamins. If the bodily functions are not kept running smoothly, the whole system breaks down. Attention should be directed toward the balancing of diets with nutrients that are utilized most efficiently in digestion with the least possible wastage in metabolism and which also tend to preserve the health of the bird.

METHODS OF FEEDING

The results secured in the feeding of any class of chickens for any particular purpose depend not only upon the proper balancing of the required nutrients comprising the diet but also upon the method of feeding employed. A well-balanced diet improperly fed will not give the most satisfactory results. Especially where the diet consists of scratch grains as well as mashes is the method of feeding important.

Free Choice of Single Feeds.—If a wide range of feeds commonly used in feeding practice was placed before chicks or hens so that they could help themselves to each feed in its separate container, the inference is natural that the birds would naturally balance their own diets. Perhaps they can and do, but some very interesting things have been learned from the "cafeteria" method of feeding.

Two of the outstanding observations made where the free-choice method of feeding single feeds has been tried are: (1) Chickens are creatures of habit and will consume large quantities of a feed largely as a

consequence of developing the habit of going to a particular container when all of the containers are left in the same place in the pen or room; (2) chickens vary a great deal among themselves with respect to their "choice" of feeds.

On the other hand, according to observations made at the Ontario Agricultural College and the Maine Agricultural Experiment Station, a group of chicks taken as a whole shows a considerable degree of consistency in the choice of feeds that supply the requirements of the different nutrients as growth proceeds. In some tests the mortality among chicks on the free-choice method has been less than among chicks in the control pen, but in other tests the reverse has been true. In the case of the Maine experiment it was found that the rate of growth was more variable among chicks on the free-choice method than among the chicks on the control method. These differences in rates of growth were believed to be due to heritable differences among the chicks with respect to their efficiency in the utilization of feed.

The free-choice method of feeding laying hens, tried out at the Ohio, Delaware, Missouri, and other agricultural experiment stations, has shown that hens vary a great deal with respect to their individual preferences for certain feeds. The idiosyncrasies among hens in their choice of feeds have been shown to be remarkable indeed, although, on the average, there are consistent differences between a group of hens laying heavily and a group laying poorly or not at all.

In view of the demonstration that chicks and hens differ among themselves with respect to the efficiency in the utilization of feed, it would seem possible to develop by proper selection and breeding methods a strain of birds uniform in their ability to utilize feed efficiently.

All-scratch Feeding.—Some farmers still rely on whole or cracked grains, sometimes providing skim milk as a drink, for growing chicks and layers. The newer knowledge of nutrition has clearly demonstrated, however, that for the most satisfactory results in growth and in the production of market and hatching eggs, the scratch grains must be balanced in nutrients by the addition of ground grains containing the necessary protein, mineral, and vitamin supplements.

Scratch and Mash Feeding.—The most popular method of feeding growing chicks and adult birds is to feed whole or cracked grains in the litter and mash in self-feeding hoppers. The scratch grains should be scattered in the litter the first thing in the morning, enough to keep the birds busy for about an hour, and again in the evening about an hour before roosting time, giving enough to enable the birds to fill their crops. Fresh mash should be placed in self-feeding hoppers as often as required, pains being taken to avoid wastage. In the case of laying birds the consumption of scratch and mash should be approximately equal.

In some cases in addition to feeding the mash in hoppers, good results have been secured with flocks of inherently high egg-laying ability by feeding the whole- or cracked-grain portion of the diet in other self-feeding hoppers.

Home Mixture plus Concentrates.—Farmers who grow their own grains and do not want to purchase either whole or ground grains have the possibility of balancing diets for various classes of chickens by purchasing mixtures of concentrates that are on the market. Care should be taken to have the home-grown grains ground so that they will mix readily with the mixture of concentrates. Any alfalfa that is used should be of a good green color.

All-mash Feeding.—During recent years considerable success has been achieved by many flock owners in feeding birds nothing but mashes, this being a common practice with birds in batteries. A choice between the all-mash and scratch-and-mash methods of feeding is largely a responsibility of the individual flock owner. The percentage of protein supplement in the all-mash feed should be one-half as great as in the mash feed that is fed in conjunction with the scratch feed.

Dry and Wet Mashes.—Dry-mash feeding involves less labor than wet-mash feeding and except under certain circumstances is preferred. On the other hand, wetting the mashes, especially if skim milk is used, tends to increase their palatability. In the feeding of chicks and layers the mash should be moistened so that it is still crumbly. In order to secure the best results in fattening, the mash should be thoroughly moistened with milk in order to secure the greatest possible feed consumption during the fattening period.

Pellets.—During recent years the feeding of pellets has gained considerable impetus in spite of the fact that it has its limitations. It is employed principally for laying hens, the dry mash being compressed under high pressure into pellets which are about 1/8 in. in diameter and about 1/4 in. in length.

The pellet method of feeding is often represented as being particularly suitable for feeding laying hens in batteries, but in this connection it may be pointed out that there is often considerable wastage of feed, especially by certain birds which seem to seek a more perfectly balanced diet or for other reasons. This method of feeding is the antithesis of the "cafeteria," or free-choice, method and presents the objection that in spite of existing knowledge pertaining to poultry nutrition and the optimum needs of the laying hen with respect to various nutrients, the pellet, after all, may not represent a perfectly balanced diet.

Oyster Shells and Grit.—Oyster shells and grit are always fed in self-feeding hoppers.

Adding Fish-liver Oils.—When cod- or other fish-liver oils are to be added to a mash mixture it is good practice to mix the amount of oil needed with a small amount of cornmeal and then mix the oiled cornmeal thoroughly with the mash mixture.

Water.—Clean water should be available at all times, its absence for any length of time being more serious than absence of feed. In freezing weather a water heater should be used, or warm water should be supplied frequently.

Using Artificial Lighting.—The use of artificial light in chicken houses is in reality a method of feeding, the real purpose being to give the birds the same length of time each day for feeding during the short days of winter as during the longer days of summer. Artificial lighting is practiced with chicks and hens in batteries and with laying stock in regular laying houses.

In the laying house one 40-watt bulb should be used for every 200 sq. ft. of floor space, in a long house the bulbs being placed about 10 ft. apart and high enough above the floor so that the roosting space will be partially lighted. Each reflector should be 4 in. in depth and 16 in. in diameter. If all-night lighting is provided, two 10-watt bulbs are sufficient for about 400 sq. ft. of floor space, because all-night lighting does not need to be so bright as for the other system of lighting.

Two systems of artificial lighting are commonly employed, lighting sufficient to give the birds 13 or 14 hr. of feeding time or lighting all night, the latter system being restricted for the most part to places where natural gas is available at low cost. Where electric current is used, three plans are possible: (1) turning the lights on about 3:30 A.M. and off when daylight comes; (2) turning the lights on at about 4:30 A.M., off at daylight, then on at dusk until about 6 P.M.; (3) turning them on at about 10 P.M. for about an hour. Of these three plans, the morning-only lighting plan is preferable because the day's work is completed when the birds go to roost and no dimming system is necessary, as is the case with the other two plans in order to permit the birds to find the roosts after the bright lights are turned off. Whichever plan of lighting is used should be followed regularly without sudden interruptions, or the birds are very liable to be thrown into a molt.

For pullets the lighting should begin about the first of September or October and should be continued until about the first of March, depending partly upon the section of the country and the condition of the birds. It should be discontinued gradually, not suddenly. The pullets should be culled closely and housed according to age. The benefits derived from lighting consists chiefly in securing a higher fall and winter egg production, although the annual egg production per bird is about the same in lighted

and unlighted pens of similar breeding under identical conditions of management except for lighting. When hens are "lighted" it is very important to regulate the feeding so that egg production will not be over-

FIG. 142.—Artificial lighting, when properly used, means increased egg production during the fall and winter months. (*Reliable Poultry Journal Publishing Company.*)

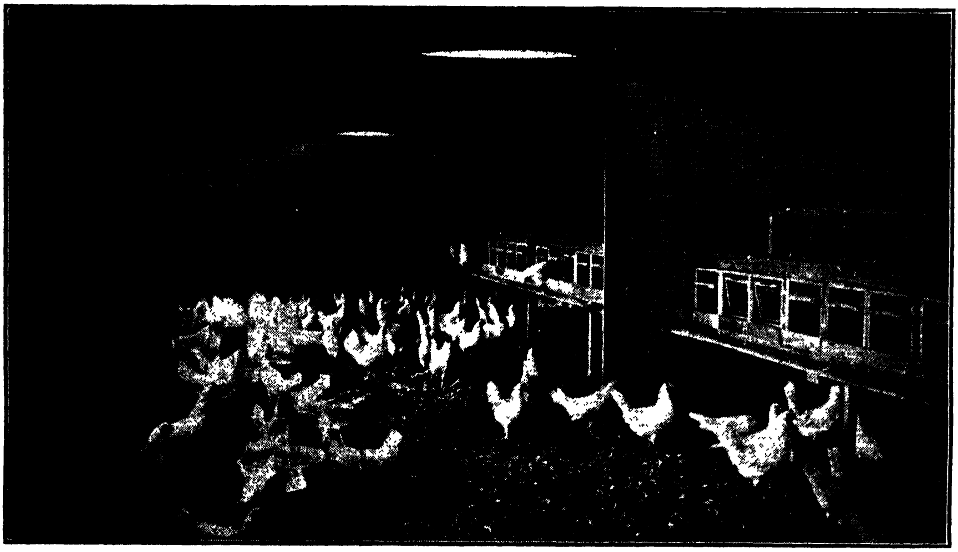


FIG. 143.—The use of artificial lights in stimulating fall and winter egg production is of particular value in the northern sections of the country. A dimming system allows the layers to retire in comfort. (*Reliable Poultry Journal Publishing Company.*)

stimulated and so that good body weight may be maintained throughout the first laying year.

A higher summer and fall egg production can sometimes be secured from hens if they are "lighted" beginning about the middle of August or

a short time before the pullets are ready to be placed in the laying house. The flock of hens should be gone over carefully, putting the best ones to be kept for breeding purposes on range, culling the poorest ones, and putting the balance in an empty brooder or other house where they are put under lights. A slight increase in the protein content of the diet might be of help to stimulate greater feed consumption and thus offset the effects of moving.

The method of feeding must be adapted to the use of artificial lights. When morning lights are used the scratch grain should be scattered in the litter the evening before. Clean water and fresh mash should always be available whenever the lights are on. Birds that are "lighted" require careful management to avoid disturbing factors that may readily affect egg production.

FORMULAS FOR PRACTICAL DIETS

Developing formulas for the most satisfactory kind of diets is dependent upon a knowledge of at least the four following factors:

1. The nutritive requirements of chickens with respect to the various purposes for which they are fed.
2. The source of the essential nutrients and the role they play in poultry nutrition.
3. Properly balancing the diet with respect to the various nutrients needed for any particular purpose.
4. The essentials of a good diet and methods of feeding.

These four sets of factors having previously been discussed in some detail, it is now possible to suggest formulas for diets for the promotion of growth, for the development of flesh in fattening, and for the production of market and hatching eggs. This can best be done by giving in the following pages some of the diets that are recommended by various state agricultural experiment stations and agricultural colleges. The formulas for these diets have been developed based on the knowledge of the four sets of factors mentioned above and have been found to give satisfactory results in practice.

Most of the formulas given are from institutions at which a considerable amount of experimental work has been underway, but it should be understood that at numerous other institutions just as much experimental work has also been underway. Lack of space prevents giving more than a few formulas, and in the choice of the institutions represented their geographical distribution played a part.

The primary purpose in giving these formulas is to furnish the reader with some conception of what constitutes a good diet. The various diets have much in common but at the same time make it clear that any two diets fed for the same purpose may contain different feeds or the same

feeds in different proportions. The relative availability and price of some of the feeds in certain sections of the country account for some of the differences in the make-up of the various diets. All of the figures given in the formulas are percentages of the mash and scratch portions of the diet, respectively, or pounds of each feed used on the basis of the mash and scratch portions each containing 100 lb.

Diets for Growing Chickens.—Some institutions recommend what is known as a "starting" diet to be fed for the first 8 or 12 weeks and a "developing" diet after that time. Others feed the same diet, perhaps with slight modifications, throughout practically the entire growing season.

CORNELL CHICK DIET

Mash Mixture	
Yellow cornmeal	40.0
Flour-wheat middlings	20.0
Wheat bran	10.0
Fine-ground heavy oats	10.0
Meat scrap (55 per cent protein)	10.0
Dried skim milk or dried buttermilk	7.5
Limestone or oyster-shell flour	2.0
Fine salt	0.5
Cod-liver oil	0.5

The mash mixture only is fed for the first 8 weeks; then the following scratch mixture is also fed:

Cracked yellow corn	50
Wheat	50

DIETS FOR CHICKS RAISED ON RANGE

Diet	Kentucky		Oklahoma	
	1 to 12 weeks	13 weeks to laying time	1 to 12 weeks	13 weeks to laying time
Mash mixture				
Ground yellow corn	25	20	25	25
Wheat bran	25	30	25	25
Wheat shorts	25	30	25	25
Dried buttermilk	10	..	5	5
Meat scrap or fish scrap	12	20		
Meat and bone scraps	..	..	5	5
Alfalfa-leaf meal	..	..	8	8
Cottonseed meal	..	..	5	5
Salt	1	1	1	1
Bone meal	2			
Powdered limestone	..	..	1	
Fish-liver oil	1		[1]	
Scratch feed				[2]
Cracked yellow corn	50	50		
Wheat	50	50		

[1] Cod-liver oil recommended if green feed and sunshine are not available.
[2] After the first 12 weeks a scratch feed of at least 3 grains is recommended.

Ontario Chick Diet

Mash Mixture

Ground yellow corn	17
Rolled wheat	16
White hominy	16
Rolled groats	15
Powdered skim milk	7
Rolled oats	5
Rolled barley	5
Wheat germ	5
Meat meal	4
Wheat bran	3
Ground peas	3
Soybean-oil meal	2
Fish meal	1
Cod-liver meal	0.5
Cod-liver oil	1 pt.

Bone meal, oyster shell, and grit are fed in hoppers.

The mash mixture only is fed for the first 6 weeks; then the following scratch mixture is also fed:

Wheat	66
Cracked corn	34

Washington State Chick Diets

Diet No. 1

Protein Supplement Incorporated in Mash

Chick Starting Mash No. 1

- 40 lb. ground yellow corn
- 10 lb. ground wheat
- 12 lb. finely ground heavy oats
- 15 lb. wheat bran
- 5 lb. dehydrated alfalfa
- 5 lb. meat scrap
- 5 lb. fish meal
- 5 lb. skim-milk powder
- 2 lb. ground oyster shell or limestone
- 1 lb. salt
- 1 lb. biologically tested cod-liver oil or fish oil or its equivalent in concentrated vitamin D

Developing Mash No. 1

- 15 lb. ground yellow corn
- 10 lb. ground wheat
- 34 lb. finely ground heavy oats
- 18 lb. millrun
- 5 lb. dehydrated alfalfa
- 5 lb. meat scrap
- 7 lb. fish meal
- 1 lb. steamed bone meal
- 4 lb. ground oyster shell or limestone
- 1 lb. salt
- 1 lb. biologically tested cod-liver oil or fish oil or its equivalent in concentrated vitamin D[1]

Diet No. 2

Protein Supplement Fed in Form of Liquid Milk

Chick Starting Mash No. 2

- 40 lb. ground yellow corn
- 20 lb. ground wheat
- 15 lb. finely ground heavy oats
- 15 lb. wheat bran
- 5 lb. dehydrated alfalfa
- 1 lb. steamed bone meal
- 3 lb. ground oyster shell or limestone
- 1 lb. salt
- 1 lb. biologically tested cod-liver oil or fish oil or its equivalent in concentrated vitamin D

Developing Mash No. 2

- 15 lb. ground yellow corn
- 20 lb. ground wheat
- 38 lb. finely ground heavy oats
- 15 lb. millrun
- 5 lb. dehydrated alfalfa
- 2 lb. steamed bone meal
- 4 lb. ground oyster shell or limestone
- 1 lb. salt
- 1 lb. biologically tested cod-liver oil or fish oil or its equivalent in concentrated vitamin D[1]

[1] During the months of June, July, August, and September, it is not necessary to use a Vitamin D oil in developing mashes No. 1 and No. 2.

SCRATCH GRAINS FOR DIETS NO. 1 AND NO. 2

Chick Scratch	Intermediate Scratch	Developing Scratch
200 lb. steel-cut wheat	200 lb. whole wheat	300 lb. whole wheat
100 lb. No. 2 fine-cracked yellow corn	100 lb. No. 2 medium-cracked yellow corn	100 lb. whole yellow corn

WISCONSIN CHICK DIET NO. 2

Mash Mixture

Ground yellow corn	45
Pure-wheat bran	15
Pure-wheat middlings	15
Meat scrap	8
Dried milk	8
Alfalfa-leaf meal	5
Oyster-shell or limestone grit	1.5
Granite grit	1.5
Iodized stock salt	0.5
Cod-liver or sardine oil	0.5

This mash mixture only is fed for the first 4 weeks, after which grains are fed, starting with wheat.

With chicks on good green pasture the alfalfa meal is omitted, and ground grains are substituted.

If skim milk is high in price and pasture is good, the skim milk is omitted after 4 to 6 weeks.

The various diets for growing chicks given above which are recommended by different institutions exhibit several interesting features. All-mash feeding for the first few weeks is generally recommended. The cereal grains, corn, wheat, oats, and barley, appear to be interchangeable, although corn is the preferred grain. The supplements used vary a great deal as between diets, although the proportion of protein supplements to grain is approximately the same in all the diets. It should be noted that feeding a scratch mixture starting at about 6 to 8 weeks results in reducing the percentage of protein in the diet. Although a high protein content is desirable for the first few weeks, it should be lowered somewhat after this period especially in the case of pullets being raised for egg production.

Diets for Broilers.—In commercial broiler production it is desirable to secure as rapid growth as possible, hence a relatively high protein content of the diet is necessary. For this reason broilers are fed diets similar to some of the mash mixtures given above up to the time the broilers are marketed, which on the average is about 12 weeks. Cockerels that are raised incidental to the raising of pullets for the replacement of the laying flocks should be separated from the pullets at from 6 to 8 weeks of age and fed much the same as before being separated. All diets for broilers should probably contain some form of milk.

Diets for Fattening.—Birds that are fed special fattening diets before being marketed include fryers, roasters, capons, sometimes broilers, and laying hens that have outlived their usefulness as layers. In the case of young birds fed a special fattening diet much of the increase in body weight is due to the growth of various tissues, but there is also a considerable amount of deposition of fat if a good fattening diet is used. Hens are frequently fat enough without being fed a fattening diet, but if

they happen to be thin in flesh a short period of fattening will prove profitable. The birds may be fattened in pens or in specially designed fattening batteries. As a matter of fact, very little fattening of poultry is now done on the farm, since most of the commercially dressed poultry is fattened in feeding stations operated by the various packing-house companies. Before being placed in the batteries the chickens should be carefully graded for condition and finish, because some birds will require to be fattened for a longer period than others.

The results secured in the fattening of poultry depend not only upon the age and condition of the birds when they are placed in the fattening batteries but also upon the kind of diet fed and the method of feeding. The birds should be sorted carefully according to size and condition. Generally speaking, three feedings daily are advisable. The fattening period should be continued as long as economical gains in weight are being made, the period usually extending from about 7 to about 21 days.

The fattening diet should be of such consistency that it will pour readily into the V-shaped trough. The proper consistency is usually obtained when about 60 per cent of water is added to the mash mixture.

While the birds are being fattened they should be kept as quiet as possible at all times. The temperature of the fattening room should be kept as even as possible, particular care being taken to avoid excessively hot weather.

MACDONALD COLLEGE FATTENING DIETS

Feed	No. 1	No. 2	No. 3	No. 4
Ground yellow corn	22.75	22.50	30.00	23.25
Ground wheat	22.75	22.50	.....	23.25
Ground oats	22.75	22.50	30.00	23.25
Ground barley	22.75	22.50	30.00	23.25
Beef meal	3.50	3.50	3.50	3.50
Powdered milk	2.50	2.50	2.50	2.50
Crude-corn oil	2.00	2.00	2.00	
Bone char or charcoal	.....	1.00	1.00	
Salt	1.00	1.00	1.00	1.00

The following suggestions are offered concerning the purpose for which each of the foregoing diets is intended:

Diet No.	
1	For commercial feeding on short periods—4 to 8 days—any class of stock. Three full feeds per day—half-hour feeding period
2	For commercial feeding where white skin and fat finish is desired. Add 1 per cent bone char or English nut charcoal to the diet
3	For pen feeding or range finishing of broilers. Dry-mash fed ad libitum in hoppers and two wet-mash feedings per day, giving as much as will be cleaned up readily

Diet No.

4....... For farm fattening (confinement in crates or pen feeding)—14-day feeding period. Three full feeds daily—½-hr. feeding period. If liquid skim milk or buttermilk is available for mixing the wet mash, the beef meal and powdered milk may be omitted from the diet.

Diets for the Developing Pullets.—Reducing the percentage of the protein content of the chick diet at about 6 to 8 weeks of age is a sound practice, particularly with respect to the pullets that are being raised for laying purposes. A high protein diet stimulates excessively rapid growth and is uneconomical because a less expensive lower protein diet not only induces sufficiently rapid growth but enables the pullets to accumulate some fat for the onset of egg production. Rearing the pullets on good range where green feed is abundant and shade available is probably the best way of preparing them as efficient layers. In many cases it is sometimes wise to close the mash hoppers about 3 o'clock in the afternoon to induce the pullets to consume more whole or cracked grain. Feeding the whole or cracked grain in hoppers has been practiced with good results. At any rate, as laying time approaches it is very important that the birds be of good body size and in the best possible condition.

Diets for Layers.—The mash mixtures listed in the table shown on p. 325 are those recommended by widely scattered institutions, although some of the institutions recommend a choice of two or more mash mixtures. In most cases scratch grain is fed in addition to the mash mixture, the birds being fed so that they consume approximately equal parts of scratch grains and mash mixture. The scratch-grain portion of the diet should preferably consist of a mixture of at least two and preferably three of the staple grains corn, wheat, oats, and barley. When the layers are confined, a good vitamin D supplement should be added to the mash mixture.

It is quite apparent from the different combinations of grains and protein supplements that it is possible to vary the mash mixture from a fairly simple to a rather complex one. As a matter of fact, many different mash mixtures can be recommended provided there is a proper balance between the grain portion and the protein-supplement portion of the mixture and also provided that protein supplements of good quality are used.

Where liquid skim milk is available as a drink it is possible to use such a simple mixture as equal parts yellow cornmeal, crushed oats, wheat bran, wheat middlings, and good-quality meat scraps, provided about 1 per cent by weight of salt and of cod-liver oil is added and good green leafy alfalfa hay is fed in a rack. Such a mash mixture may not be so well balanced as it should be but is a good mixture for practical farm use where liquid skim milk is available.

Diets for Molting Hens.—In almost any flock the molting process extends from early summer to late fall, the poorest layers usually beginning to molt much earlier in the season than the best layers. In order to have the molting of the entire flock completed fairly early in the season so that the flock will lay at a good rate in the fall when egg prices are high, some flock owners practice the forced molting of their flocks. Birds

Laying-mash Mixtures

California	Pounds	Ontario	Pounds
Yellow corn meal	30	Ground yellow corn	20
Ground barley	15	Rolled wheat	22.5
Wheat bran	15	Crushed oats	15
Ground wheat	10	White-hominy feed	10
Fish meal, 65 per cent crude protein	12.5	Wheat germ	7.5
Alfalfa meal	7.5	Corn feed or yellow hominy	5
Dried skim milk	5.0	Rolled barley	5
Bone meal	2.0	Meat meal	4
Ground limestone or oyster shell	2.0	Wheat bran	2.5
Salt	1.0	Banner-oat feed	2.5
		Powdered milk	1.5
		Fish meal	1.5
		Ground soybean-oil meal	1
		Ground peas	1
		Cod-liver meal	0.5
		Iodized salt	0.5
Texas	**Pounds**	**Wisconsin**	**Pounds**
Ground corn or milo maize	20	Wheat bran	28.25
Wheat bran	20	Wheat middlings	28.25
Wheat gray shorts	20	Ground yellow corn	19
Ground whole oats	15	Meat scrap	14.5
Meat and bone scrap	10	Dried milk	4.5
Sardine meal	10	Alfalfa meal	4.5
Alfalfa-leaf meal	3	Salt	1
Chick-size oyster shell	1		
Salt	1		

that were hatched before the first of April are much better suited for forced molting than later hatched birds, and only flocks that are in good physical condition should be force molted. The Washington State College of Agriculture recommends a strict procedure for successful forced molting.

The period between July 1 and July 15 is considered the best time for starting to force molt the flock, which should be culled thoroughly. The first step in forcing the molt is to remove all mash, withhold water for

24 hr., and then remove the water every afternoon until egg production takes a drastic drop. Artificial lights should not be used. Feed grain sparingly, using mostly heavy whole oats, allowing about 6 lb. daily per 100 birds. Feed green feed and cod-liver oil but no milk, and keep hard granite grit in the hoppers. The molting period usually requires from 15 to 23 days.

The resting period starts after most of the feathers have been shed and continues for approximately 6 weeks. The birds should have access to good range and should be fed 3 lb. of wheat bran daily per 100 birds in addition to about 9 lb. of grain in three feedings daily in deep litter. An abundant supply of fresh water should be available at all times but no milk. Artificial lights should not be used. Hard granite grit and oyster shell should be kept in the hoppers.

Beginning with the seventh week the birds should be confined to the house, put on a 14-hr. day of artificial lighting, and fed laying mash and 7 to 9 lb. of scratch grains daily per 100 birds. Add cod-liver oil to the mash. Plenty of water should be given as well as green feed or fresh yellow carrots, and hard granite grit and oyster shell should be available in hoppers. During the next 6 months egg production should not be expected to exceed an average of 45 to 60 per cent.

Diets for Breeders.—The diet for breeding stock should be designed primarily for the production of eggs of the highest possible quality. It is essentially the same as the diet for layers except that greater care should be taken to see that it contains an abundance of vitamins D, E, riboflavin and the filtrate factor and is well balanced with respect to calcium and phosphorus. The two following diets show how these various factors are presumably provided for.

Diets for Breeders

Pennsylvania	Pounds	Washington	Pounds
Mash mixture		Mash mixture	
Ground yellow corn	34.5	Mill run	27
Wheat bran	15	Ground yellow corn	15
Wheat middlings	15	Ground wheat	15
Ground heavy oats	10	Ground oats	10
Alfalfa meal	7	Dehydrated alfalfa	10
Dried milk	7	Meat scrap, 55 per cent protein	6.5
Meat scrap	5	Fish meal, 70 per cent protein	6.5
Fish meal	5	Powdered skim milk	5
Finely ground oyster shell	1	Ground oyster shell	2
Salt	0.5	Bone meal	2
Cod-liver or sardine oil	2	Salt	1
		Cod-liver oil	2
Scratch mixture		Scratch mixture	
Whole or cracked corn	50	Whole wheat	60
Wheat	50	Whole yellow corn	40

Whether or not diets such as those given here for breeding females are the best also for breeding males has never been determined, but judging from the results in fertility and hatchability of eggs produced by many flocks of males and females fed these or similar diets it is presumed that they are satisfactory.

FEED CONSUMPTION IN RELATION TO GROWTH AND EGG PRODUCTION

The amount of feed consumed by chickens in a given time or to produce a certain gain in body weight is of very great interest to the flock owner, because the cost of feed is the largest single cost factor in raising chickens or in egg production. The amount of feed necessary for the production of broilers, roasters, or eggs is determined by a large number of factors, including the inherent capacity for growth, the ability to utilize feed efficiently, the laying ability, the kind of diet, and the method of feeding. Each factor plays its part in its respective field and must be taken into consideration.

For those who desire to know the approximate number of pounds of feed consumed and average body weights attained at different ages, the following table is given.

TABLE 48.—FEED CONSUMPTION AND WEIGHT OF SINGLE-COMB WHITE LEGHORN CHICKS GROWN IN CONFINEMENT
(Charles and Knandel, 1928)

Weeks	Weekly feed consumption per 100 chicks, pounds			Average weight per chick, pounds
	Grain	Mash	Total	
1	1.11	13.99	15.10	0.117
2	4.99	22.30	27.29	0.190
3	8.28	24.10	32.38	0.303
4	11.78	27.49	39.27	0.444
5	16.24	35.25	51.49	0.565
6[1]	21.38	37.47	58.85	0.787
7	28.16	41.46	69.62	0.898
8	30.11	47.41	77.52	1.104
9	32.27	46.18	78.45	1.202
10	38.00	52.40	90.40	1.38
11	43.26	46.39	89.65	1.58
12	49.59	39.10	88.69	1.69
13	48.47	46.07	94.54	1.87
14	48.41	46.83	95.24	2.07
15	53.75	41.66	95.41	2.42
16	57.93	50.26	108.19	2.51
17	60.97	42.88	103.85	2.75
18	67.33	53.01	120.34	2.82
19	63.75	62.50	126.25	3.02
Total.........	685.78	776.75	1,462.53	

[1] Cockerels removed at the end of sixth week.

Since feed consumption is of relatively greater importance than age in determining gain in body weight, the poultryman should be interested in knowing the approximate number of pounds of feed required to produce a chicken of a certain body weight. Broiler producers as well as those who raise fryers and roasters should be very much interested in data such as those given in the following table.

TABLE 49.—THE AMOUNT OF FEED REQUIRED TO OBTAIN CERTAIN SELECTED AVERAGE LIVE WEIGHTS WITH DIFFERENT CLASSES OF CHICKENS
(Titus, 1937)

Average live weight, pounds	Feed required per bird, pounds		
	W. Leghorns, males and females[1]	Crossbreds,[2] males	R. I. Reds, males
0.5	1.38	1.29	1.12
1.0	3.18	2.91	2.53
1.5	5.27	4.65	4.05
2.0	7.75	6.52	5.69
2.5	10.80	8.56	7.49
3.0	14.75	10.78	9.46
3.5	20.39	13.24	11.66
4.0	.....	15.97	14.13
4.5	.....	19.07	16.95
5.0	.....	22.62	20.25

[1] For a group containing approximately the same number of birds of each sex.
[2] The male offspring resulting from mating Barred Plymouth Rock females to Rhode Island Red males.

Comparable data for Crossbred and Rhode Island Red females would be approximately 10 per cent below the values given for the males.

The amount of feed consumed during the fattening period is influenced by the size of the birds being fattened, the kind of diet being fed, the weather, and other environmental factors. In an extensive series of fattening trials conducted at Macdonald College it was found that roasters weighing about 5.5 lb. on the average consumed approximately 2.50, 2.75, 3.75, and 5.75 lb. of feed when fattened for 7, 10, 14, and 21 days, respectively.

The amount of feed consumed by laying pullets during the first year of egg production has been determined at several institutions, the more important factors affecting the amount consumed being the kind of diet, the size of the birds, and the number of eggs laid. From data obtained at a number of state experiment stations it is found that Leghorns laying an average of approximately 150 eggs per bird consume about 70 to 85 lb. of feed per year and that Plymouth Rocks and other breeds of similar size with an average egg production of 150 eggs consume about 80 to

95 lb. per year. The relationship between egg production and feed consumption is borne out by the data in the following table, which gives the average number of pounds of feed required to produce one dozen eggs by groups of White Leghorns differing in average egg production per bird.

TABLE 50.—POUNDS OF FEED CONSUMED PER DOZEN EGGS PRODUCED, ACCORDING TO AVERAGE EGG PRODUCTION PER BIRD, IN WHITE LEGHORNS
(Waite, 1934)

Average egg production per bird	Average No. pounds feed consumed per bird	Average No. pounds feed per dozen eggs
117.7	69.30	7.06
136.6	71.41	6.28
145.0	73.25	6.06
156.3	75.32	5.78
165.8	76.67	5.55
175.0	77.82	5.34
185.0	78.64	5.10
194.4	80.99	5.00
204.8	81.02	4.75
214.8	81.84	4.57
224.6	83.48	4.46
234.1	84.28	4.32
243.9	85.36	4.20
253.9	87.03	4.11
269.2	83.73	3.73

The data in this table show that the higher the egg production the greater the feed consumption per bird but the fewer the number of pounds of feed required to produce a dozen eggs. The poor layers used relatively more of the feed that they consumed for maintenance of body weight than the good producers.

EFFECT OF FEED ON PRODUCT

The results of studies on the effect of feed on the physical and chemical composition of poultry meat and eggs are of immense importance to producers because of their possible relationship to consumer demand for poultry products of various kinds. Research work carried on during recent years has demonstrated that for the most part the chemical composition of poultry meat and eggs is not altered significantly by the diet that the birds are given. On the other hand, it has been demonstrated repeatedly that diet does have an important bearing on some of the physical properties of poultry products.

Diet, Composition and Quality of Flesh.—As the result of observations made at Macdonald College in Canada, Cambridge University in England, the National Agricultural Research Center in the United States, and other institutions, it may be stated that diet has little effect on the chemical composition of the carcass but that the percentage of fat in the carcass is increased, of course, as the result of fattening.

Work at the National Agricultural Research Center has shown that, as the result of fattening, relatively large quantities of fat and water are deposited in the adipose tissues of the cockerels. Although the total fat content of the body increases considerably in the case of mature birds on a good fattening diet, the percentage increase in the water content of the edible portions is greater than that of fat. It has also been demonstrated that the vitamin A content of the livers of chicks that received 0.5 per cent of sardine oil as a supplement to their diet was about four times greater than that of the livers from chicks that received 0.25 per cent of sardine oil. Work at the University of California demonstrated a direct correlation between the storage of vitamin A in the liver of chickens and the vitamin A content of the diet.

On the other hand, as the result of observations made at Macdonald College, it would appear that the protein and fat content of the carcass was not significantly influenced by the protein level of the diet.

Work with the four cereal grains, cornmeal, ground wheat, ground oats, and ground barley, at Macdonald College showed that the deposition of fat varied according to the cereal used. The differences are probably not significant, however, judging by the results of fattening trials conducted by the Canadian Department of Agriculture.

TABLE 51.—DISTRIBUTION OF THE CARCASS FAT OF RHODE ISLAND RED COCKERELS FATTENED 21 DAYS ON SINGLE-GRAIN DIETS
(Maw, 1935)

Cereal diet	Distribution of carcass fat, percentage in		
	Flesh	Skin	Abdomen
Cornmeal	30	55	15
Ground barley	26	59	15
Ground oats	22	57	21
Ground wheat	20	60	20

Birds fattened on either ground oats or ground wheat have a much lighter colored skin than those fattened on either cornmeal or ground barley. Those fattened on cornmeal when tasted were adjudged as being superior in flavor and moisture content of flesh; whereas the birds fed on

ground wheat were regarded as lacking in flavor, and the flesh was dry. The flesh of the barley- and oat-fed birds was intermediate.

The hardness or softness of the fat deposited during fattening is influenced by the character of the fattening diet, as shown by the results secured at Cambridge University. Cereal grains produce a moderately soft carcass fat. If mutton fat is added to the fattening diet, this practice having sometimes prevailed in England, the carcass fat is inclined to be quite hard, whereas when linseed and certain other oils are added to the diet the carcass fat is inclined to be very soft. Palm oil fed at a level of 8 per cent of the fattening diet was found to produce a desirable carcass fat, palatability tests of roasted birds giving favorable results.

The color and flavor of the carcass may be affected by diet. It has already been observed that a yellow-corn fattening diet produces a bright yellow-colored carcass, whereas wheat- and oats-fattened birds have a whitish-colored carcass. Bone char added to the fattening diet in small quantities produces a light-colored skin, regardless of the amount of yellow corn used. Cod- or other fish-liver oils, if fed up to slaughter time, sometimes produce a "fishy" flavor in the flesh; the oil should not be fed for at least 2 weeks previous to slaughtering.

Diet, Composition and Quality of Eggs.—The results secured at the National Agricultural Research Center from feeding several diets that differed rather widely show quite conclusively that the chemical composition of eggs is influenced to a very slight extent by diet. The white of the egg was less affected than the yolk. Eggs from hens fed diets derived chiefly from plant sources contained more fat in the dry matter of the yolks but less protein in the dry matter of the white than eggs from hens fed diets of much simpler composition. A diet containing crab meal as the only source of animal protein led to the production of eggs containing a greater percentage of protein but a smaller percentage of fat in the dry matter of the yolks than the eggs produced from all other diets tested. Even then the difference was small.

Although it has been pointed out previously that according to the Cambridge University findings there is a close relationship between the fats contained in the diet and those deposited in the body of the fowl, the relationship does not hold to the same extent with respect to the fats deposited in the yolk. The California Experiment Station has shown that fat deposited in the body is not used to any important extent in the formation of yolk fat. The Cambridge University findings were to the effect that while the degree of saturation and the proportion of the component fatty acids could be modified considerably by the ingestion of unsaturated fatty acids, the ingestion of saturated acids had relatively little effect in altering the normal composition of the mixed fatty acids of the egg fat.

It is well known that diet has a very direct effect on the color of the yolk, diets containing green feed producing much darker yellow-colored yolks than similar diets minus the green feed. Yellow corn produces much darker yellow-colored yolks than white corn. Green feeds and yellow corn are relatively rich in a pigment called "xanthophyll," and dark yellow-colored yolks are also rich in the same pigment. At the same time, it should be noted that hens can deposit several other pigments in the yolk, *e.g.*, Sudan III, the pigments of pimiento pepper and the pigments of Chili pepper. Hens fed relatively large amounts of pimiento pepper lay eggs the yolks of which are yellow-red in appearance.

The change from light to dark yellow eggs follows within a day or two after pigmented feeds are added to the diet. Since some markets discriminate against eggs having dark yellow yolks, some poultrymen make a practice of keeping their laying birds confined until sometime in the afternoon for the purpose of reducing the amount of grass or other green feed consumed. In so far as known, no evidence has been presented to show that the amount of green feed consumed or that diet in general has any bearing on the production of "watery eggs."

The Kansas Experiment Station has reported that two members of the mustard family, Shepherd's purse and penny cress, impart an olive color to yolks, but the Oklahoma Experiment Station failed to note any yolk discoloration after feeding all the chopped Shepherd's purse that birds would eat three times daily for 2 months. The same was found to be true of penny cress, although but little was consumed. The feeding of rape also failed to discolor the yolks.

Hens fed diets containing 30 per cent of linseed meal or soybean meal laid eggs with discolored yolks, according to the Oklahoma Experiment Station findings. The same levels of peanut meal and corn-gluten meal failed to produce discolored yolks. Work at the Delaware Experiment Station showed that an all-mash diet could contain as much as 10.4 per cent of ground soybeans without affecting yolk color or the keeping quality of eggs stored as long as 9 months. Cottonseed meal when fed above a 5 per cent level in the diet produces discolored yolks, the free or bound gossypol of the cottonseed being the causative factor, according to the Michigan Experiment Station.

The California Experiment Station has shown that hens consuming considerable quantities of common cheese weed lay eggs the whites of which have a pinkish color after the eggs have been placed in cold storage.

When hens are fed a normal diet, lutein and zeaxanthin are the chief caroteinoid pigments of the xanthophyll group present in egg yolks, the other pigments being cryptoxanthin and carotene. The Kansas Experiment Station has shown that as the xanthophyll content of the diet was increased the xanthophylls deposited in the egg yolk increased. The

results secured at the Western Washington Experiment Station indicate, however, that as the quantity of xanthophylls transmitted to the yolk are increased, relatively larger quantities of xanthophyl pigments are required in the diet to produce noticeable changes in the yolk.

In a general sense, at least, there is a relationship between the color of the yolk and its vitamin A content, the higher the yellow color of the yolk the richer being its content in vitamin A. An exception, by way of illustration, might be noted in the feeding of a diet of white corn supplemented by cod-liver oil which might conceivably lead to the production of eggs with relatively pale-colored yellow yolks of high vitamin A content. At Cambridge University it was found that the administration of cod-liver oil to a laying hen at the rate of 10 per cent of the diet, which was otherwise low in vitamin A and carotene, resulted in the doubling of the vitamin A content of the eggs laid. In the same experiment it was found that the intensive administration of vitamin A raised the concentration of the vitamin A content in the egg to about five times the level found in the basal diet. It was concluded that the transfer of vitamin A to the egg is limited and decreases relatively as the intake increases.

According to observations made at the Ohio Experiment Station, the vitamin D secreted into the egg is in the same biological form as fed to the laying bird. The storage of vitamin D in the yolk was found to be proportional to the vitamin D content of the diet up to a level of 2 per cent cod-liver oil, according to work done by the U. S. Department of Agriculture.

Evidence was obtained at Cornell University that the vitamin G content of eggs and the greenish-yellow pigment of the whites of eggs were directly related to the riboflavin-vitamin content of the diet.

At the Kentucky Experiment Station it was demonstrated that the addition of 2 per cent cod-liver oil to a basal diet resulted in increasing the iron and copper contents of the yolks. Admitting hens to direct sunshine resulted in an increase in the iron and copper content of the yolks over the yolks of eggs laid by hens that received light only through ordinary window glass. Sunshine and cod-liver oil seemed to have a cumulative effect on the copper content but an antagonistic effect on the iron content of egg yolk.

Work at the Minnesota Experiment Station has shown that the addition of iodine to the diet of the laying hen had no effect on egg quality.

The flavor of eggs is sometimes affected by diet, although definite evidence is limited. The Oklahoma Experiment Station demonstrated that 5 g. of garlic pods twice daily imparted a distinct garlic flavor to the yolk 5 days after the first feeding but that the whites did not take on garlic flavor until the thirtieth day after the first feeding. The same institution found that when two No. 3 capsules of cod-liver oil were given

twice daily to hens the yolks of their eggs had a distinct fishy flavor the thirtieth day after the first feeding, and the flavor was retained after 6 months of storage. No evidence has ever been presented, however, showing that cod- or other fish-liver oils fed at normal levels in the diet impart a fishy flavor to the yolks of eggs.

Observations made at the Kansas Experiment Station demonstrate quite clearly that diet has an effect on both the flavor and the odor of eggs, greater variation being noted in the odor than in the flavor of eggs tested from different flocks fed different diets.

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CHAPTER X

DISEASE PREVENTION

The high mortality that occurs annually in the chick and adult flocks of the country is the outstanding drawback of the entire poultry industry. Few other livestock industries suffering comparable losses from mortality could carry on from year to year. Apparently, the poultry industry is able to carry on because the chicken is a small economic unit which can be readily replaced at relatively little expense.

Among growing chicks the mortality resulting from various diseases has always been a factor of considerable economic importance. Death losses are still far higher than they should be but, fortunately, in many flocks are apparently lower on the average than a few years ago. In a comprehensive survey of chick mortality conducted by the California Experiment Station it has been shown that the peak of growing-chick mortality occurs on approximately the fifth day. From surveys that have been made and from observations in the laboratories, it has been shown that by far the greatest losses from growing-chick mortality occur during the first 6 weeks of rearing. This suggests the necessity of providing optimum environmental conditions in brooding chicks and seeing to it that chicks are secured from the best possible sources of breeding stock.

The number of laying flocks that are practically wiped out because of disease occurs with increasing frequency each successive year. To the individual flock owner the loss of his flock is a tragedy, but what makes the disease problem still more serious is the fact that the mortality that occurs annually among laying flocks has shown an upward trend during the past few years. A very general picture of the main problem in mortality may be gained from a glance at the mortality figures in Table 52, from two outstanding egg-laying contests.

In view of the situation revealed in Table 52, the question may well be asked: What of the future?

Not only is the economic loss from dead chicks and hens very great, but in addition there should also be counted the cost of retarded growth, poorly finished market birds, and decreased egg production among the birds that manage to live but are infested with parasites and infected with disease organisms.

The numerous disorders and diseases to which chickens fall a prey assume enormous importance because of their mass effect rather than as

ailments of individual birds. As long as flock owners consider the mortality problem from the standpoint of treating sick chickens rather than from that of doing everything possible to prevent the occurrence and spread of disease in the flock, just that long will relatively little be accomplished in reducing the tragic losses from mortality. The preservation of the health of the flock is of far greater importance to a flock owner than trying to save a few individuals that become afflicted.

TABLE 52.—MORTALITY AMONG LAYING HENS IN THE STORRS (CONNECTICUT) AND HARPER ADAMS (ENGLAND) EGG-LAYING CONTESTS

Year	Per cent mortality	
	Storrs	Harper Adams
1919 to 1920	8.2	
1920 to 1921	12.8	
1921 to 1922	13.8	
1922 to 1923	17.1	4.6
1923 to 1924	16.5	6.1
1924 to 1925	19.8	5.6
1925 to 1926	19.6	5.4
1926 to 1927	21.0	6.6
1927 to 1928	....	7.3
1928 to 1929	....	7.1
1929 to 1930	21.6	8.8
1930 to 1931	20.1	10.7
1931 to 1932	23.9	15.4
1932 to 1933	25.6	14.8
1933 to 1934	22.2	16.4
1934 to 1935	24.5	20.0

Granted that individual birds could be "cured," there is still the possibility that they would continue to harbor the infective agent and thus be a means of spreading the disease. To a large extent poultry diseases are the result of biological causes that are transmissible. Not only is there the danger of exposing healthy birds to diseased birds, but there is always the danger of dissemination of disease through infected soil, contaminated water, and filthy quarters. Unbalanced diets, poor housing conditions, and faulty management may lower the natural resistance of birds so that they become an easy prey to disease organisms of various kinds. The mass effect of disease dissemination has long since become a very important problem in poultry husbandry.

Disease Dissemination.—Disease is regarded as any deviation from health, and in order to appreciate the ease with which it may be disseminated it is necessary to have at least a very general understanding of its nature and its causative agents.

When a disease-inducing agent, such as bacteria and viruses, gains entrance to the body, the bird is said to be "infected." The degree of the invasive power of a disease-inducing agent to cause any deviation from health is referred to as "virulence." An organism capable of producing infection is called a "pathogen." The ability of an organism or other agent to cause disease is called "pathogenic," whereas "resistance" refers to the ability of the body to resist invasion by any infectious agent, and "immunity" implies that the body is not susceptible to the pathogenic powers of the disease-inducing agent.

A brief reference to certain terms commonly used in the literature of diseases may enable the reader more clearly to understand the more important problems involved in combating disease dissemination. The condition in body tissues characterized by heat, redness, swelling, and pain is referred to as "inflammation," whereas a "lesion" denotes a visible morbid change in the color, structure, or size of an organ or part of the body. A suspension of a living, disease-inducing agent is called a "vaccine," and a suspension of dead organisms is called a "bacterin." A poisonous substance produced by certain of the bacteria is called a "toxin." The blood serum of a bird that is immune to any specific disease-inducing agent is referred to as "antiserum," and the serum of a bird that is immune to a specific toxin is referred to as "antitoxin."

Disease may result from the invasions of protozoa, bacteria, viruses, and molds or from the infestation of external or internal parasites. Protozoa are one-celled organisms and are the simplest kind found in the animal kingdom. Bacteria are one-celled, microscopic plants occurring in three principal shapes, which are referred to as bacilli, cocci, and spirillae. Viruses are so minute that they are able to pass through laboratory filters that retain the ordinary types of bacteria. A few molds or fungi, constituting the lower forms of the plant kingdom, are capable of producing disease in poultry.

A disease may be infectious or noninfectious, the difference depending upon whether or not the disease was due to any infectious agent. The pullorum disease is infectious, whereas a disease resulting from vitamin deficiency is noninfectious. From the standpoint of their transmissibility, diseases are referred to as being contagious or noncontagious, the difference depending upon whether or not the disease is transmitted to a susceptible bird. Roup and avian tuberculosis are contagious diseases, whereas perosis or slipped tendon and pendulous crop are noncontagious.

The problem of poultry disease, in reality, involves perpetual warfare between disease-inducing organisms and the hosts upon which they prey. Fortunately, in a normal state of health the chick and the laying hen possess a defensive mechanism which enables them to resist the attacks of the invading organisms with varying degrees of success.

The first line of defense is the skin, which, as long as it is not injured, offers a considerable degree of resistance to millions of organisms of vari-

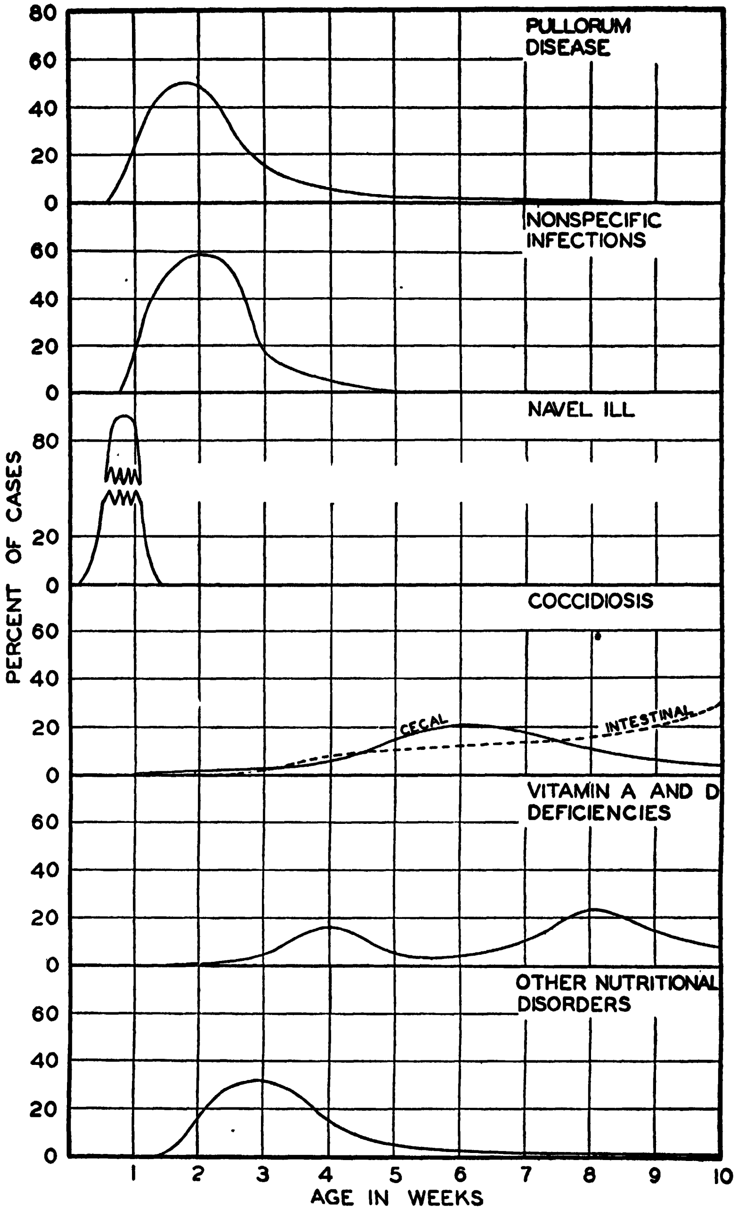

FIG. 144.—Showing the relation of age to incidence of some common chick diseases. (*Jungherr*, 1935.)

ous kinds which abound in contaminated soil and filthy drinking water and hide in poultry houses.

The second line of defense is the lining membranes of the digestive tract, which also resist invasion with a considerable degree of success

unless they are seriously injured by internal parasites or are weakened by an unbalanced diet, especially if the feed is contaminated with disease-inducing agents.

The third line of defense is the blood stream, which contains certain types of white blood corpuscles which are able to destroy the invading organisms by ingesting them.

The fourth line of defense is the presence in the blood serum of certain protective substances called "antibodies," produced by an antitoxin reacting to the presence of the toxin carried by the invading organism.

The fifth line of defense is "natural resistance."

It is obvious, therefore, that once the invading organism has passed the fourth line of defense and gained a foothold in the blood stream, the relentless warfare between the chicken and the invading organisms continues until one overcomes the other. If the defensive mechanism of the chicken is capable of overcoming the invasion, recovery follows. If, on the other hand, the unwise selection of breeding stock, the feeding of improperly balanced diets, allowing birds to range on contaminated soil, faulty methods of flock management, or other undesirable practices in poultry husbandry so weaken the chicken's defensive mechanism that it is overcome by the continuous attacks of the invading organisms, the final consequence is usually death.

The increase in the trend of mortality that has occurred during the last few years suggests that two things have taken place: (1) Some of the poultry-husbandry practices being followed tend to weaken the chicken's defensive mechanism against disease invasion; and (2) there has been more widespread dissemination of disease-inducing organisms. Disease is disseminated by means of water, soil, and air; and in many cases the rate of dissemination has been increased as the result of keeping chickens on the same land year after year. The rate of dissemination is still further increased if the land is never cultivated or sown to green crops and is covered with puddles of filthy water.

Disease is disseminated by means of contact between infected and healthy birds and by the contact of healthy birds with contaminated soil and water. Birds that have recovered from an infection may become carriers of disease-inducing organisms. Flock attendants frequently carry the organisms on their hands, shoes, clothing, and utensils from bird to bird in a flock and from flock to flock. Contaminated feed spreads disease. The hatching in the same incubator of eggs from many different flocks, securing baby chicks from several different sources, and shipping birds from laying contests and poultry shows to widely scattered places are important factors in the dissemination of various diseases. Pigeons, sparrows, and other wild birds often play the role of disease disseminators by carrying the organisms on their feet to distant communities. Flies,

fleas, and other insects frequently serve as disseminators of disease without themselves being infected.

A fact often overlooked is that with an increasing number of agencies always at work in disseminating disease, the number of birds exposed to infection is continually increasing. Moreover, with an increase in the number of birds that become infected the situation becomes further aggravated by still more widespread dissemination.

The real problem facing poultry raisers is not so much knowing how to combat or control disease as how to prevent disease from making its appearance. Curing sick chickens will probably never help the poultry industry much. The obligation rests upon every flock owner to assist the chicken in every way possible in maintaining or even improving its defensive mechanism against the invasions of disease-inducing organisms. Poultrymen must also assume their proper share of responsibility in the widespread dissemination of disease that is constantly going on and take immediate steps to lessen the hazards from increased exposure to infection.

Since so many factors are involved in the appearance and spread of poultry diseases, it is obvious that any flock owner wishing to adopt an intelligent plan of disease prevention must have some knowledge of the causative agents and how they are transmitted. The following pages in this chapter are devoted to the ethology, or study of the causative agents, of various diseases with suggestions as to best methods of preventing disease from making its appearance or what to do if it has made its appearance.

MINOR DISORDERS AND OTHER CONDITIONS

Any attempt to train every flock owner to become competent in the diagnosis and treatment of poultry diseases would be a hopeless task. Moreover, to medicate chickens is for the most part of doubtful value except in the case of valuable birds. Then, again, it should not be forgotten that a chicken that has been cured of an infectious disease may become a carrier of the causative agent of the disease. There are several minor disorders, however, that are amenable to treatment, which in many cases is justified because of the simplicity of procedure.

Frozen Comb and Wattles.—The freezing of the comb and wattles is of rather common occurrence in cold weather in northern sections of the country. If many birds in the flock suffer, both fertility and egg production may be affected. The proper treatment consists in thawing with cold water or snow and rubbing with vaseline. The trouble may be avoided by dubbing.

Dubbing Combs and Wattles.—Many poultrymen practice dubbing of the combs and wattles for the purpose of avoiding trouble from freezing and also from fighting, among White Leghorn and other males with large

combs. Dubbing is usually done at about 3 months of age, although baby chicks may be dubbed. In this case, sharp scissors may be used without excessive bleeding. Older birds may be dubbed with scissors or tinner's shears, excessive bleeding being avoided by laying a feather or sprinkling flour or mash over the cut surface.

Edema of Wattles.—The tissue of the wattle may be greatly enlarged as the result of becoming filled with an inflammatory fluid. At first the wattle is red; then it turns yellowish gray, the liquid sometimes developing into cheesy nodules. The most effective preventive measure is dubbing.

Necrosis of the Beak.—The feeding of excessively finely ground grains as a mash mixture to baby chicks in battery brooders at Macdonald College was found to give rise to a condition where particles of feed adhere to the outer edges of the beak and remain under the tongue, causing inflammation. A granular-mash mixture was found to prevent the condition from developing.

Cannibalism.—Chicks' and adult birds' picking at each other until blood shows and then destroying one another by further picking is a source of great loss in many flocks, especially when kept in confinement.

When the trouble develops among baby chicks it is sometimes very difficult to control as long as they are kept confined. Chicks that have been picked should be removed at once and may be treated with paint or tar and later put back with the rest of the chicks. The Washington Experiment Station recommends using 60- or 100-watt natural-colored ruby Mazda bulbs, glass not inside frosted, all other light being excluded. Where electric current is not available the inside of the brooder-house windows should be painted or sprayed with an opaque, flat-finish, dark red lacquer. In case the chicks must be kept confined they should be given ample floor space although probably the most effective preventive measure is to allow the chicks on good grass range.

When the trouble develops in laying flocks the same procedure may be followed as for chicks, although the usual method followed by poultrymen is to use some of the different devices that have been invented for preventing birds from picking at each other. Some of these are inserted in the beak, and some attached to the body under the vent. The recommendation of the Ohio Experiment Station of cutting back the tip of the upper beak has been found to be effective until the beak grows out again.

At the Western Washington Experiment Station it was found that feather picking was much less prevalent when the pullets were reared on a diet of ground oats instead of corn, wheat, or barley as the only cereal grain in the mash mixture. The "oats" diet, however, resulted in the development of a number of cases of impacted crops. The most effective measure of preventing cannibalism seems to be to give the birds good grass

range, although in the winter time in the northern sections of the country this is not possible.

Impacted Crop.—The accumulation of feed in the crop due to the obstruction of the opening to the lower esophagus or to paralysis of the walls of the crop may cause the crop to become so impacted that relief must be given or the bird dies. By first giving the bird water and then holding the head downward, it is sometimes possible to massage the crop to force the food out through the mouth.

The only other method of relief is apparently to remove the feed by making a 1-in. incision through the skin and the wall of the crop, on the upper front surface so that it will be on the top side of the crop when the bird is standing. The crop should be washed out with warm water, and then the incisions in the wall of the crop and in the skin should be sewn up separately with white silk or cotton thread. Each suture should be tied separately. Neither feed nor water should be given for several hours, the first feed being a well-moistened mash.

Pendulous Crop.—This is different from the impacted crop, since the pendulous crop is almost empty of feed, but relief may be secured by removing a portion of the wall of the crop, using the same method as prescribed above.

Egg Bound.—This condition may be relieved by inserting a finger, covered with carbolized vaseline, into the cloaca and expelling the egg by the manipulation of the other hand.

Prolapsus.—Birds in their first laying year, especially pullets just beginning to lay, sometimes suffer an eversion of the oviduct, probably due to straining or from other causes. According to observations made by workers at the Michigan Experiment Station, coccidia and intestinal worms are predisposing factors. Cases of prolapse may be treated by washing the tissue with warm water and gently pushing it back in place. The bird should be kept in a quiet place, and cold water may be injected into the cloaca. It is very important to remove all cases of prolapse from the flock as soon as discovered; otherwise cannibalism may develop on an extensive scale.

Egg Eating.—This bad habit, rather than disorder, may be entirely prevented by providing darkened nests.

Heat Prostration.—In extremely hot weather prostration from heat may occur. Affected birds should be removed to a cool place and if necessary doused in cool water. Commercial broiler producers have sometimes resorted to using a fire engine to spray water over the brooder houses. It is important never to have the brooder or laying houses too crowded, and wherever possible ample shade should be provided. The laying houses should be provided with ventilated nests, and if trap-nesting is carried on care should be taken to release the hens at frequent intervals.

Bumblefoot.—When the bottom of the foot is badly bruised or cut, an abscess may develop. The scab may be removed, and the pus forced out, applications of an antiseptic solution applied, and the foot bandaged.

Spurs Trimmed.—In the case of breeding male birds it is sometimes advisable to trim the long, sharp spurs to prevent the backs of females from being torn. A saw or knife should be used, making sure that the end of the spur is left blunt. The development of spurs may be prevented by cutting off the spur cap of young cockerels close to the leg and rubbing potassium hydroxide (caustic potash) on the wound. Leghorns should be about 12 weeks old, and heavier breeds about 15 weeks old when the treatment is applied.

EXTERNAL PARASITES

If external parasites are not kept under reasonable control, considerable economic loss may be suffered from the standpoints of stunted growth in the young stock and decreased egg production among the layers. There is a multiplicity of external parasites, including principally lice, mites, ticks, and fleas. Since they prey upon the host externally, it is apparent that good husbandry is necessary to prevent their appearance or keep them under control. To the practical poultryman suggestions concerning management methods for the prevention and control of external parasites are of more importance than a knowledge of their life histories, despite the fact that rather complete knowledge of the latter was necessary before successful preventive and control methods could be recommended.

Lice.—These are small yellowish- or grayish-colored insects which have cutting or biting mouth parts, and since they multiply rapidly their numbers are so increased that a lousy bird suffers considerable discomfort. Lice complete their life cycle on the body of the host and can live only a few days off the body. There are about 50 different species of chicken lice, all belonging to the order Mallophaga. They do not suck blood.

The head louse (*Lipeurus heterographus*) is found about the head and neck. It is probably the species most injurious to young chicks.

The wing louse (*L. variabilis*) is found especially under the primary feathers of the wings.

The fluff louse (*Goniocotes hologaster*) is not of much economic importance.

The large hen louse (*G. abdominalis*) is less abundant than the fluff louse and is easily recognized by its large size and its smoky gray to blackish markings.

The shaft louse (*Menopon gallinae*) apparently feeds almost entirely on the barbs of the feathers and on the scales along the shaft.

The small body louse (*M. pallidum*) is light in color and smaller than the large head louse, but its habits are similar.

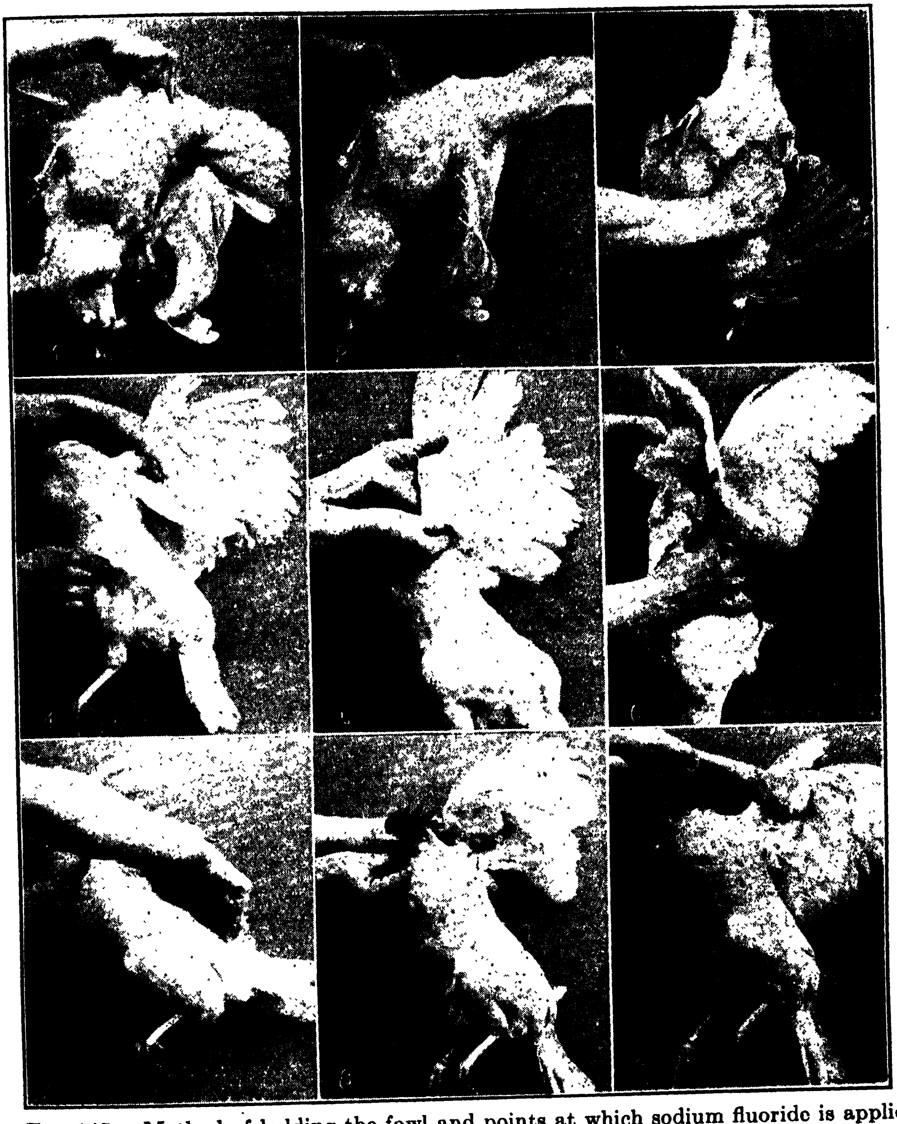

FIG. 145.—Method of holding the fowl and points at which sodium fluoride is applied when using dust method. Note that each figure shows the bird held in the same manner. The following is the order of application: (*a*) base of tail, 1; (*b*) below the vent, 2; (*c*) to one side of keel bone, 3; (*d*) other side of keel bone; (*e*) outside thigh region (left), 4; (*f*) along wing (left), 5; (*g*) on back, just back of wings, 6; (*h*) base of tail, 7; (*i*) outside thigh region (right); (*j*) along wing (right); (*k*) throat, 8; (*l*) back of head, 9. (*Western Wash. Exp. Sta.*)

The common large louse (*M. stramineum*) is perhaps the most common species. It stays close to the skin.

Since lice spend their life cycle upon the host, it is obvious that treatment should be directed largely to the host. However, there may at

times be danger of reinfestation from the litter and molted feathers; therefore, a thorough cleaning of the house and burning of the litter are desirable whenever a flock becomes badly infested. Since most treatments recommended are not sufficiently powerful to kill the eggs of lice, a second treatment should be applied about 10 days to 2 weeks after the first, in order to kill the newly hatched lice. Also, it is very important to treat every bird in the flock if the treatment is an individual one, since one untreated bird may serve to reinfest the entire flock.

Various dusts may be used to rid fowls of lice. Sodium fluoride and sodium fluosilicate are most effective and may be applied by the so-called "pinch method"; *i.e.*, a pinch is put on the breast, on each thigh, below the vent, on each side of the back, on the neck, on the head, and finally on the underside of each outspread wing. These two substances may also be sprinkled over the bird, the powder being rubbed thoroughly over the skin.

The use of dips is a quicker method than with powders, though dipping should be done only in fine weather. Sodium fluoride at the rate of 1 oz. of the commercial or ¾ oz. of the c. p. product is added to each gallon of tepid water contained in a wooden bucket. The wings are held in one hand, the feet in another, and the bird is submerged for about half a minute. After the bird is drained the head is next submerged. Sodium fluosilicate may be used to replace the fluoride. An ounce of laundry soap dissolved in a gallon of water may be used. This treatment does not kill the eggs and must be repeated in 10 days to 2 weeks. Dips should be used in warm weather only, and there should be no breeze. The operation should be stopped early enough in the day to give the birds a couple of hours in which to dry before the sun goes down.

Ointments may be used in certain cases, although more time is usually required than with powders or dips. Carbolated petrolatum is quite satisfactory for head lice in young chicks, and lard may be used on the head and under the wings of baby chicks.

One part mercurial ointment mixed with two parts petrolatum has been found effective for treating adult birds. A piece of ointment the size of a pea should be applied beneath the wings and around the vent and rubbed in well to prevent poisoning. One application is said to be sufficient for complete extermination of all lice. Birds producing eggs for hatching and sitting hens should not be treated with mercurial ointment or hatchability may be lowered.

One of the most practical methods of controlling lice is by the use of 40 per cent nicotine sulfate painted on the roosts. The application should be made just before the birds go to roost, and treatment should be applied to all roosting places. Three or four drops of the liquid also should be put in each nest. The house should not be closed too tightly, as birds have

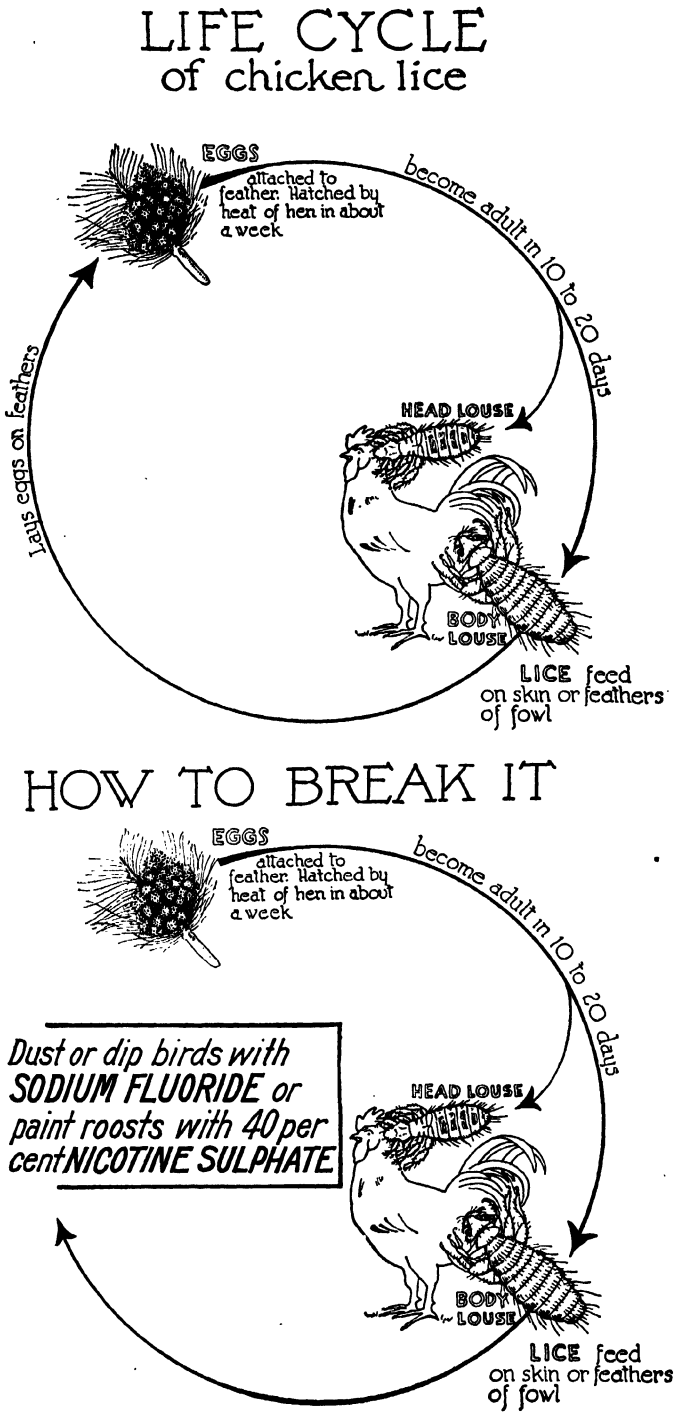

FIG. 146.—Lice are easily controlled by dusting or dipping the birds individually with sodium fluoride or by painting the roosts with nicotine sulfate. (*Adapted from original by U. S. Dept. Agr.*)

been known to die from nicotine sulfate in poor ventilation. A second treatment should be applied in 10 days to 2 weeks. This is apparently the most effective treatment available.

Mites.—There are many species of mites, some of them very destructive, others of little consequence.

The air-sac mite (*Cytoleichus nudus*) is discovered by an examination of the abdominal air sacs where the mites are seen as small grayish or light yellow specks. They are usually seen only in old birds kept in filthy surroundings. There is no successful treatment.

The common chicken mite (*Dermanyssus gallinae*) is referred to as the "roost mite" and the "red mite." These mites visit their prey at night, only a few being found on the birds during the day. "Salt-and-pepper markings," the droppings of mites, on the roosts indicate that the cracks and crevices in the house contain myriads of these pests. Treatment should be directed to the cracks and crevices, and all litter should be removed and burned. Several agents may be used, but a thorough application should be made of whichever is chosen. Wood preservers having anthracene oil as a base are effective. A 3 per cent solution of a miscible tree-spray oil is also quite effective.

The connective-tissue mite (*Laminosioptes cysticola*) is found in the connective tissue beneath the skin and between the muscles of birds kept under such conditions as described for air-sac mites. The damage caused is questionable, and there is no successful treatment.

The depluming mite (*Cnemidocoptes gallinae*) may sometimes cause serious trouble through irritation and may practically denude birds of their feathers. One of the most effective treatments is to dip each bird in a tub of tepid water containing 2 oz. of flowers of sulfur and 1 oz. of laundry soap to each gallon of water.

The scaly-leg mite (*Cnemidocoptes mutans*) causes an eruption of the scales on the shanks of chickens. Remove infested birds from the rest of the flock. In mild cases thorough treatment is quite successful. The shanks should be dried thoroughly and should then be treated with an ointment containing 2 per cent of carbolic acid or a mixture of 1 part oil of caraway with 5 parts vaseline.

The northern fowl mite (*Liponyssus silviarum*) swarms on the birds and may be found on them at any time. Finely divided sulfur as a dust may be used in cold weather, but dipping is more advisable, although it can be done only in summer. An ounce of soap is dissolved in warm water, and to this is added 2 oz. of sulfur. The mixture is stirred frequently to keep the sulfur in suspension. Nicotine sulfate applied to the roosts just before roosting time every 3 days for three times has been found effective.

The tropical fowl mite (*L. bursa*) is similar in habits to the northern fowl mite and should receive the same treatment.

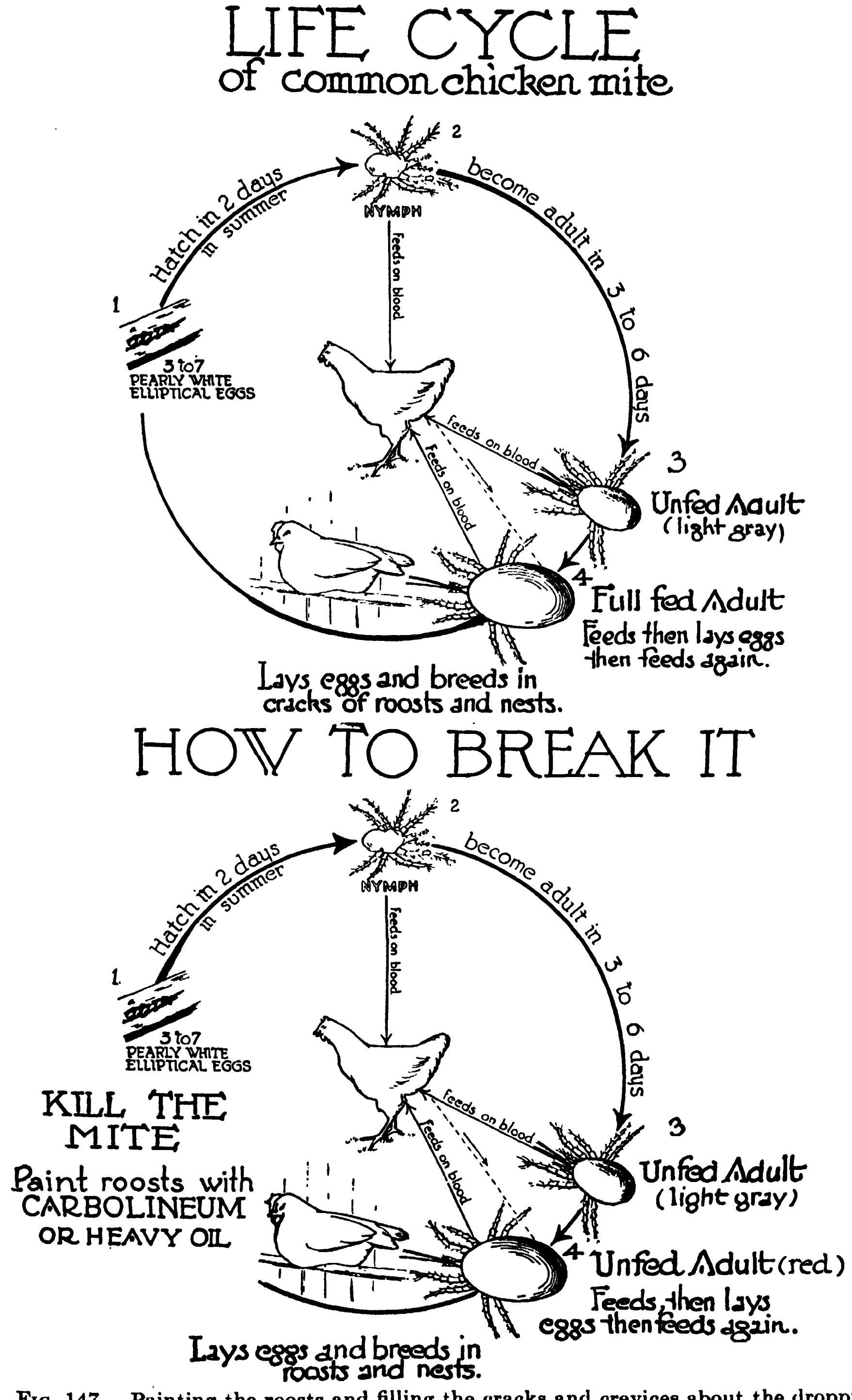

FIG. 147.—Painting the roosts and filling the cracks and crevices about the droppings boards and nests control mites, if done properly and at the right time. (*Modified from the original by U. S. Dept. Agr.*)

Chiggers.—These "red bugs," or red mites (*Trombicula spp.*), may become attached to chickens while walking in fields and sometimes cause intense irritation. An application of sulfur ointment is recommended.

The Fowl Tick.—The chicken tick (*Argas persicus*) is sometimes a serious pest. It is a bloodsucker and feeds at night only, hiding by day in cracks and crevices, where the young are hatched. The young ticks crawl upon the birds while they roost. Penetrating materials must be used and must be applied at intervals because of the complicated life history and the length of time the tick is able to go without food. The most effective treatment reported is carbolineum, a wood preserver containing anthracene oil. The U. S. Department of Agriculture officials recommend supporting all roosts from the roof of the poultry house because the tick has the tendency of always crawling upward.

The Sticktight Flea.—The sticktight flea (*Echidnophaga gallinacea*) has become a serious pest in certain sections of the southern parts of the United States. Attaching themselves to the appendages of the bird's head, these fleas remain attached by their mouth parts for 4 to 19 days and are very difficult to remove. They succumb only to extremes of heat (100°F.) and cold (freezing). Other animals, including cats and dogs, should be excluded from the poultry yards, and when a flock becomes infested, the house should be cleaned thoroughly and sprayed with creosote oil. United States Department of Agriculture officials also recommend spraying the poultry yard with creosote oil. Birds may be treated individually by applying sulfur ointment or carbolated pretolatum.

Other External Parasites.—There are several other external parasites that have been observed to attack chickens, including bedbugs, beetle larvae, cystic flukes and black flies. For the most part they are not economically important.

INTERNAL PARASITES

Chickens on range are always seeking food in the superficial layers of the soil, which is often thoroughly contaminated with living organisms of all kinds, including the eggs of worms that are parasitic to chickens. Land that is bare, rarely cultivated, and over which chickens range year after year is a particularly favorable breeding ground for many of the internal parasites. Chickens kept indoors or allowed on sun porches are also apt to become infested as the result of worm eggs being carried into the house on shoes or through contact with some of the intermediate hosts necessary for the completion of the life cycle of the parasite. Birds that become badly infested are rarely profitable and always constitute a menace to all other members of the flocks. "Worming" the infested birds to *control* worm infestation is a poor substitute for sanitation to *prevent* it.

Capillaria Worms.—There are many species of these small parasitic worms which invade the crop, esophagus, small intestine, and caeca of the chicken and sometimes do considerable damage. They have a direct cycle of reproduction; *i.e.*, the female worm lays its eggs while in the invaded organ, the eggs are voided with the chicken's droppings, and under suitable conditions of moisture and temperature they embryonate and become infectious. During the process of embryonation a very small worm develops within the egg which when devoured by the chicken liberates the worm from its shell, the worm completing its development within the chicken's intestinal tract. A bird heavily infested with capillaria worms loses weight and becomes listless. Every possible preventive measure, particularly sanitary quarters and clean, dry range, should be resorted to in order to protect the birds from infestation. For treatment, carbon tetrachloride administered in 1-cc. doses has been found effective against some of the species.

Caecal Worms.—This parasite (*Heterakis gallinae*) invades the caeca, sometimes causing severe inflammation. It is a small grayish-white, slender worm up to about ½ in. in length and has a direct life cycle, although two species of dung earthworms have been found to be capable of transmitting the caecal worm to chickens. Chicks and adult birds heavily infested in general lose weight and become unthrifty.

Strict yard sanitation, with rotation of yards, especially for growing chicks, is the most effective preventive measure. When many birds in a flock are infested, the whole flock may be given the tobacco-dust treatment, 2 per cent by weight of tobacco dust containing not more than 1.5 per cent of nicotine being added to the dry-mash mixture, giving this feed for at least one month. Since tobacco dust soon loses its nicotine content upon being exposed to the air, this mixture should be made up fresh in small quantities at a time.

A method of treatment for caecal-worm infestation in individual cases is to administer oil of chenopodium by rectal injections. A stock mixture is made up consisting of 1 teaspoonful (1 fluid drachm) of oil of chenopodium in 12 tablespoonsful (6 fluid ounces) of cottonseed or corn oil. By means of a suitable syringe, 3 teaspoons of the stock mixture is injected slowly into the rectum, this being the proper dose for birds weighing about 1½ lb.

Eyeworms.—The eyeworm (*Oxyspirura mansoni*) infests chickens by becoming lodged under the nictating membrane of the eye, thus causing irritation and inflammation so that the bird winks continuously and scratches its eye or rubs it against the body. The eyeworm has an indirect life cycle, the cockroach serving as intermediate host. The eggs of the eyeworm are passed down the tear duct to the bird's mouth and are subsequently voided with the droppings. The cockroach eats the egg or

newly hatched larvae, and when the cockroach is devoured by the chicken the young eyeworms are released and make their way to the nictating membrane of the chicken's eye.

Strict sanitation in houses and yards is a necessary preventive measure against cockroaches. For treatment, the Florida Experiment Station recommends instilling into the eye a few drops of butyn (local anesthetic), then lifting the nictating membrane and placing 1 or 2 drops of a 5 per cent solution of creolin directly on the eyeworms, which are about ¾ in. long. The eye should be thoroughly irrigated with clean water immediately after instilling the creolin.

Gapeworms.—The chicken gapeworm (*Syngamus trachea*) attacks the trachea of chickens and is most harmful with growing chicks. It is unique in that the male and female remain permanently attached to each other, the male being up to ¼ in. long, and the female up to ¾ in. long. The disruption of the female is necessary to liberate her eggs, which are expelled with the chicken's droppings, young embryos developing under suitable conditions. Earthworms sometimes serve as intermediate hosts. Eggs containing embryos, embryos that have hatched, or earthworms containing the larvae, if eaten by fowls, migrate to the trachea where they cause inflammation and the accumulation of mucus, which causes the chicken to sneeze and "gape" for air. The chicken loses weight, and death from suffocation may ensue.

Preventive measures include frequent cleaning of the poultry houses and keeping chickens away from turkeys, because turkeys may be infested without apparent injury to themselves but constantly serve as a source of infestation for chickens. Successful treatment is extremely difficult, rotating a coiled horsehair in the trachea usually proving only partially successful.

Gizzard Worms.—Inasmuch as the gizzard worm (*Cheilospirura hamulosa*) is a small parasite that buries itself in the thick muscles of the gizzard, it has been found practically impossible to prescribe an effective treatment. The internal symptoms consist of nodules on the surface of the gizzard, and there are no specific external symptoms. Two species of grasshoppers serve as intermediate hosts, thus making it difficult adequately to provide proper preventive measures.

Large Intestinal Roundworms.—The large intestinal roundworm (*Ascaridia lineata*) infests the small intestine, for the most part, and is a very serious menace in many flocks, especially where no reasonable preventive measures are undertaken. It has a direct reproductive cycle, its egg being voided in the chicken's droppings and under suitable environmental conditions developing into a young embryo, which when devoured by the chicken continues its development in the small intestine, sometimes reaching a length of 4 in. Definite external symptoms of heavy round-

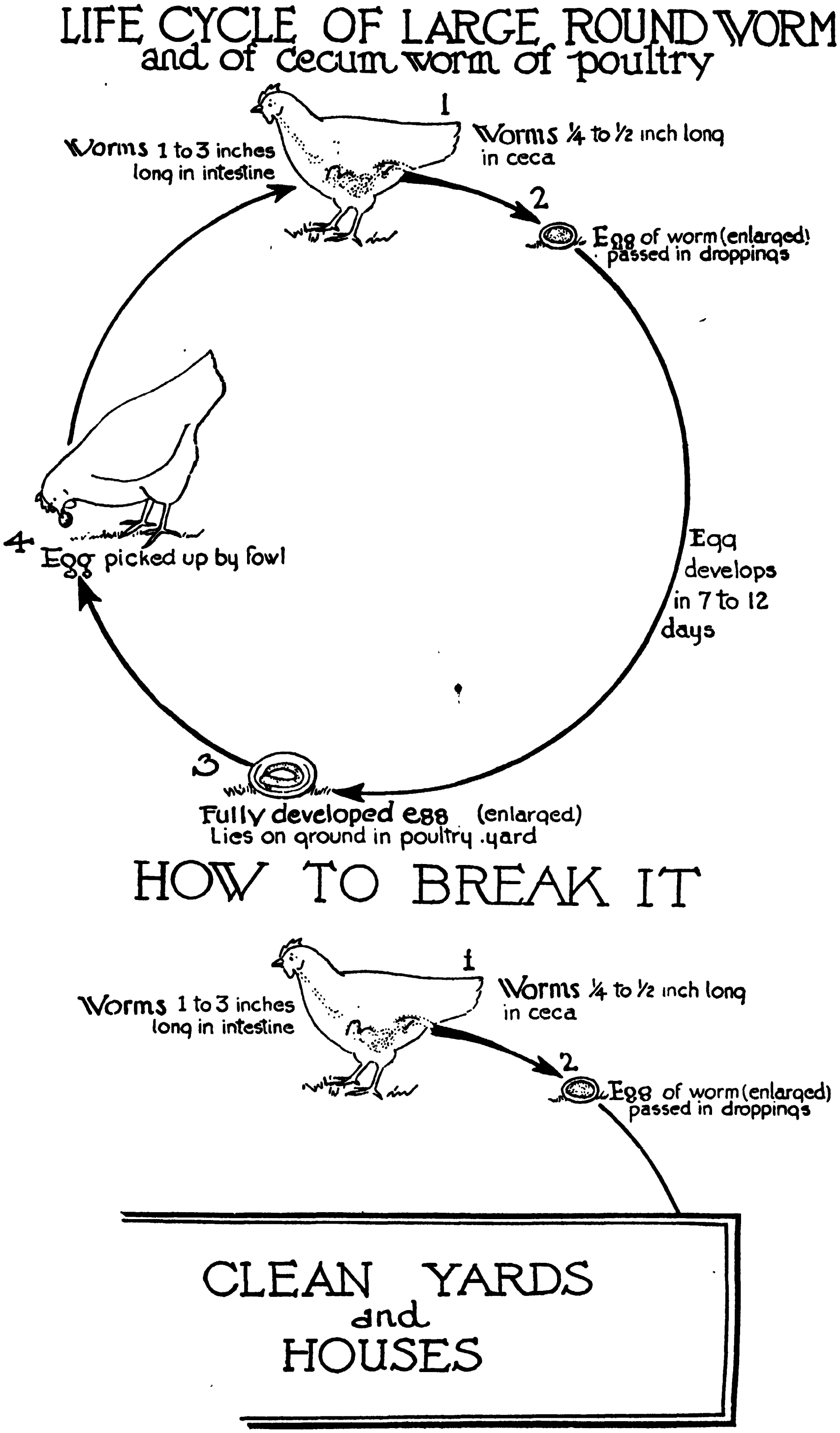

FIG. 148.—Proper sanitation is an important factor in controlling round worms and caeca worms. (*Modified from original by U. S. Dept. Agr.*)

worm infestation are recognizable, the chickens losing weight, becoming emaciated, and having ruffled feathers, bleached beaks and shanks, and in some cases lameness.

A sanitary yarding system, involving the use of alternate yards on which green grass or other vegetation is grown, followed by cultivation and reseeding, is one of the most effective measures of prevention. Sanitary houses combined with the removal of the litter at intervals of 10 days will help in preventing roundworm eggs from developing into the infectious stage. Sanitary yards and houses for growing chicks are of the utmost importance, a necessary prerequisite being the complete separation of growing chicks from adult birds.

When a flock of birds becomes heavily infested it may be given the tobacco-dust treatment. The Pennsylvania Experiment Station found that using a diet containing 0.4 per cent by weight of ground tobacco of the *Nicotiana rustica* strain, which has a nicotine content equal to 5 per cent of its dry weight, was effective in controlling roundworm infestation. The tobacco-dust-mash mixture should be fed for about 4 weeks.

For treating individual birds the California Experiment Station recommends using a mixture of 6.6 cc. of nicotine sulfate thoroughly mixed with 16 g. of Lloyd's Alkaloidal reagent. One dose of this mixed powder consists of 0.35 to 0.4 g. in a No. 2 capsule, which is administered by placing the capsule well back in the bird's throat and then from the outside of the throat forcing it into the crop with the aid of the thumb and forefinger. A No. 2 capsule is a safe dose for birds over 2 months old. The Kansas Experiment Station found that carbon tetrachloride in gelatin capsules at the dose rate of 4 cc. per kilogram of body weight was effective in expelling intestinal roundworms and that in chicks there were no toxic effects but that in laying pullets egg production was materially lowered for a period of about 10 days.

After feeding the tobacco-dust-mash mixture or giving the No. 2 capsules the poultry house should be cleaned thoroughly, and the litter burned. If only a few birds are treated with No. 2 capsules they should be kept separate from the rest of the flock until all roundworms have been passed.

Small Intestinal Roundworms.—The small intestinal roundworm (*Strongyloides avium*) inhabits the caeca of chickens, causing a thickening of the caecal wall and in severe cases bloody diarrhea. Apparently no effective treatment has been devised, sanitary yards and houses for the growing chicks being the best preventive measure.

Spiral Proventriculus Worms.—This roundworm (*Dispharynx spiralis*) infests the proventriculus of chickens but is not common. Two species of sow bugs serve as intermediate hosts, so that clean houses and yards are necessary preventive measures.

Tetramere Proventriculus Worms.—This parasite (*Tetrameres americana*) also infests the proventriculus of chickens. The life cycle is indirect, cockroaches and grasshoppers serving as intermediate hosts. This makes it difficult to prescribe preventive measures, and apparently no effective treatment has as yet been devised.

Tapeworms.—There are several different species of tapeworms that infest chickens, some being very minute, while others may attain a length of 12 in. The most commonly encountered tapeworms in a Michigan survey were *Raillietina cesticillus* and *Hymenolepis carioca.* The life cycle of all tapeworms, in so far as it has been determined, is indirect, the housefly, worms, beetles, and other insects serving as intermediate hosts.

The tapeworm attaches itself to the wall of the intestine by its head, behind which new segments continue to be formed, the sections farthest from the head being the egg-producing segments. As new segments are formed, the terminal ones are cast off and are voided with the chicken's droppings. The eggs in the expelled segments upon being eaten by any of the numerous intermediate hosts develop into the infectious stage, and when the chicken devours one of these intermediate hosts the young tapeworms are released in the intestinal tract and attach themselves to the wall of the intestine. A very large number of tapeworms may be observed in the more severely infested cases.

Since tapeworms feed upon the fluids of the intestinal wall, the severity of the infestation increases the drain on the bird's system until emaciation precedes death.

Preventive measures include clean houses and clean yards as well as well-balanced diets to enable the birds to withstand the strain upon the digestive system.

In view of the fact that tapeworms attach themselves to the wall of the intestine by means of hooks and suckers, it is apparent that effective treatment would naturally be very difficult. Most remedies that have been tried have unfortunately proved largely ineffectual. The Michigan Experiment Station has recently reported that iodione vermicide is of some value.

Flukes.—The fluke of the Prosthogonimus species has been observed in the ovary, oviduct, and cloaca of chickens. It is reddish brown in color and about ¼ in. long and has a complicated life cycle, the snail being the first intermediate host followed by the dragonfly as the second necessary intermediate host. As a preventive measure chickens should not be allowed access to low, wet areas commonly inhabited by flukes.

Another fluke (*Psilostomum ondatrae*) has been reported to infest the proventriculus, causing enlargement and inflammation. In one case, snails were believed to serve as the intermediate hosts, and when they were eliminated no further trouble was encountered.

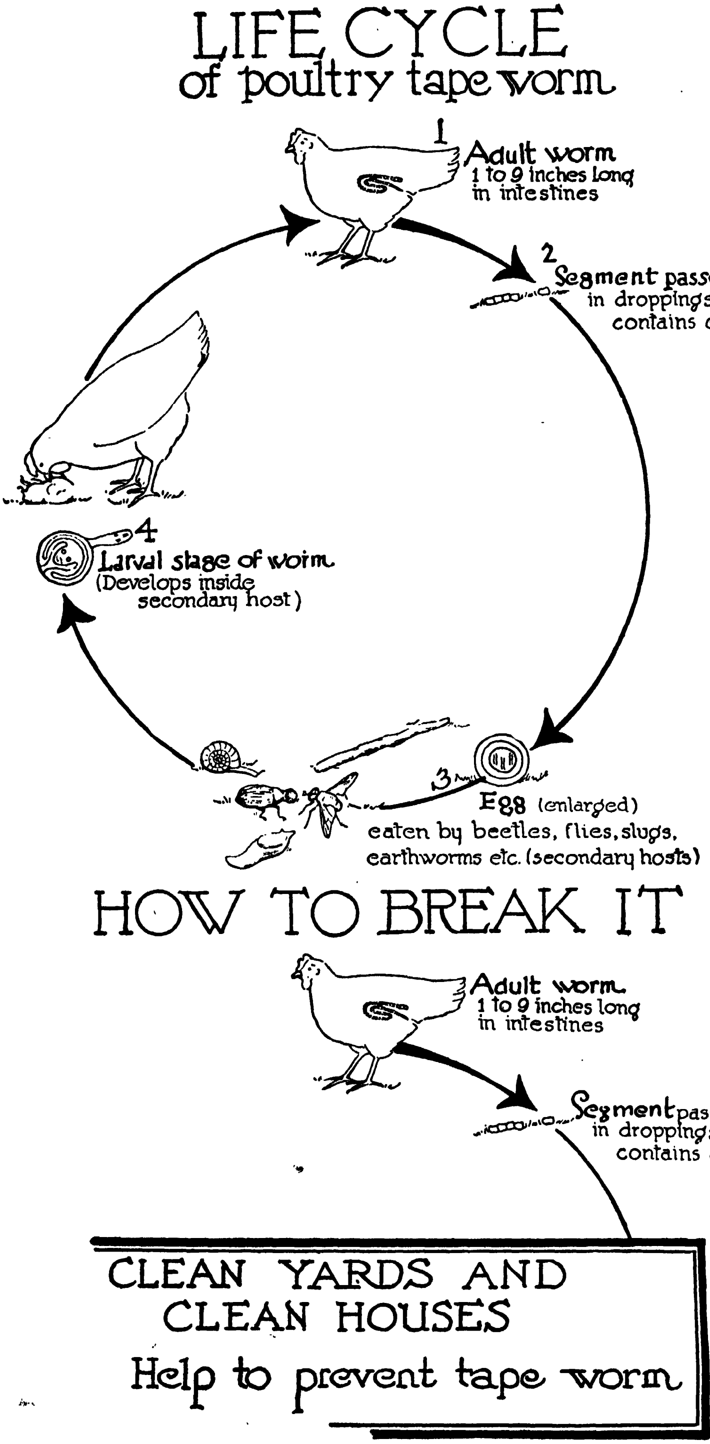

FIG. 149.—Sanitation is an important factor in controlling tapeworms. (*Modified from the original by U. S. Dept. Agr.*)

NUTRITIONAL DISORDERS

During the past few years research work on poultry nutrition has demonstrated most clearly that chickens must be fed reasonably well-balanced diets, or they will suffer in one of several different ways. Properly balanced diets are of fundamental importance in promoting the physiological well-being of the chicken and in maintaining its health, especially in the case of birds kept in strict confinement. Apparently sunshine, green grass, and other "outdoor" feeds contain something that is not provided in most of the diets that have been compounded.

As pointed out in the two preceding chapters, chicks raised indoors suffer from rickets because of a lack of vitamin D unless certain supplementary sources of the vitamin are added to the diet. The proper calcification of bone depends not only upon an adequate supply of vitamin D but also upon the available supplies of calcium and phosphorus, which must be in correct proportions one to the other in order to give best results. Manganese, and perhaps other minerals, are necessary in the diet of the growing chick to prevent perosis or slipped tendon.

Research work has also shown that other vitamins besides D must be present in adequate amounts both for chicks and for laying hens. For satisfactory market- and hatching-egg production the hen must have abundant supplies of A, B, and E as well as other vitamins. Riboflavin and the filtrate factor are two vitamins necessary for promoting normal growth.

The quality of protein contained in the diet has been shown to be of importance, particularly with respect to its free fatty-acid content.

In these and in other ways research work has demonstrated that faulty diets sometimes cause serious consequences in malnutrition, although it should be pointed out here that when chicks and adult stock are allowed in the sunshine and have access to a good range of green grass there is little likelihood of their diets being deficient in any important respect. The various deficiency diseases of dietary origin have already been discussed in the two preceding chapters, so that it is necessary to discuss only very briefly here a few other nutritional disorders not specifically discussed previously.

Anemia.—It has been demonstrated that chicks raised on an all-milk diet develop an anemic condition by the time they are about 3 weeks old, demonstrating a deficiency of iron and copper.

Fatty Liver.—This condition has been observed by workers at the Connecticut Experiment Station in chicks that died between the fourth and seventh day of brooding, the liver being intense yellow in color and filled with minute globules of fat. The cause is unknown, and the condition has not become a serious menace.

Goiter.—Although goiter has been known to occur in fowls, it has not been demonstrated to be of serious consequence, nor have experiment-station tests demonstrated the necessity of adding iodine to ordinary poultry diets.

Gout.—This disorder has been observed in chicks but is more usually found in adult birds and is believed to be due to some disturbance in the utilization of proteins in the feed. The kidneys are pale and enlarged, frequently being coated with a whitish sugarlike material, a similar condition sometimes also being found on the lining of the abdomen and the surface of the liver. Injury to the kidneys is very apt to disturb the normal elimination of uric acid, which tends to accumulate in a precipitated form and sometimes gives rise to uremic poisoning.

Gout may be associated with vitamin A deficiency, although it is supposed to be due primarily to an excessively high level of protein. Recommendations in the way of a cure include lowering the protein level of the diet and feeding a mash containing 10 per cent of alfalfa-leaf meal.

Nutritional Encephalomalacia.—Chicks up to 2 months of age are susceptible to this disease, which affects the brain. External symptoms include stupor, tremors, head twisting, and convulsive spasms of the legs. It has been reported that 2.4 mg. daily per chick of the nonsaponifiable fraction of soybean oil affords protection against the disease.

Protein Poisoning.—Under the popular name of "crazy-chick" disease, this has been observed most frequently in rapidly growing chicks between the second and fifth weeks of age. The characteristic symptoms include a lack of balance associated with lack of muscular control and occasionally a twisting of the head. The kidneys are enlarged and congested. The exact cause has not been determined, and about the only recommendation that has been made is to give a mild milk flush and change the diet.

PROTOZOAN DISEASES

A protozoon (plural, protozoa) is the smallest kind of animal in existence and is a one-celled creature, some forms of which cause considerable damage in the higher forms of animal life, including chickens. Although blackhead and certain other protozoan diseases are important, by far the most outstanding one from the standpoint of economic importance is coccidiosis, which derives its name from the fact that the causative agent is a protozoan form of animal life called "coccidia." There are other protozoan forms that are parasites to chickens, but for the most part at present they are of relatively little consequence.

Blackhead.—This disease, called "infectious enterohepatitis," is caused by the protozoan parasite *Histomonas meleagridis* and is much

more commonly found in turkeys than in chickens. The parasites inhabit the caeca and in a certain stage of development gain access to the blood stream by means of the liver.

Caecal worms in the caeca sometimes become infected with the blackhead organism, and when the worm lays its eggs, some of the organisms are contained within the eggs. When these eggs are voided with the chicken's droppings they are protected for some time and then may be picked up by other chickens, which become infected with blackhead and infested with caecal worms.

No satisfactory medical treatment is known. Since chickens may contract blackhead, however, it is obvious that they may serve as carriers to transmit the disease to turkeys, in which the disease is highly fatal. It is obvious, therefore, that chickens and turkeys should never be allowed together, nor should they be allowed access to the same land.

Coccidiosis.—Heavy mortality sometimes results from coccidiosis, especially in young chicks up to 2 months of age. The disease is caused by a very small protozoan organism, which multiplies very rapidly in the intestines of chickens. Six species of coccidia have been identified: *Eimeria tenella, Eimeria mitis, Eimeria acervulina, Eimeria maxima, Eimeria necatrix,* and *Eimeria praecox. Eimeria tenella* produces caecal coccidiosis, and the others produce intestinal coccidiosis.

The life cycle of the coccidium is a complicated one, involving an asexual as well as a sexual cycle. The organism, expelled with the droppings, is termed an "oocyst." Under favorable environmental conditions the oocysts undergo a process known as "sporulation" and develop into sporocysts. When devoured by a chicken along with feed, the sporocysts, in the intestinal tract, give rise to spindle-shaped bodies called "sporozoites," which are released from the oocyst shell and enter the epithelial cells of the walls of the intestine where they finally develop into schizonts, which in turn give rise to merozoites. While embedded in the epithelial cells of the walls of the chicken's intestine the merozoite develops into a schizont so that the usual cycle involves the development of schizonts into merozoites and back again into schizonts, this repeated process causing severe damage to the mucous membrane of the wall of the intestine of the chicken.

The sexual cycle emerges when the merozoites, instead of forming schizonts, give rise to the formation of male and female cells, which unite to produce oocysts. The oocysts are expelled with the chicken's droppings and upon sporulation become infective organisms ready to be devoured by the chicken to carry on further reinfestation. From about 4 to 10 days are usually required for the sporulation of the oocysts to take place, a very important point to remember in any control measures undertaken.

Chicks heavily infected with coccidiosis become droopy, look unthrifty, usually have ruffled feathers and pale beaks and shanks, and eventually become so emaciated that death follows. The mortality in a flock may be high and may occur very suddenly. Chicks that apparently recover from the disease may have the disease in chronic form as adults. Old birds that have become immune to the disease are a constant source of reinfection. No old birds should ever be allowed on the range with growing chicks.

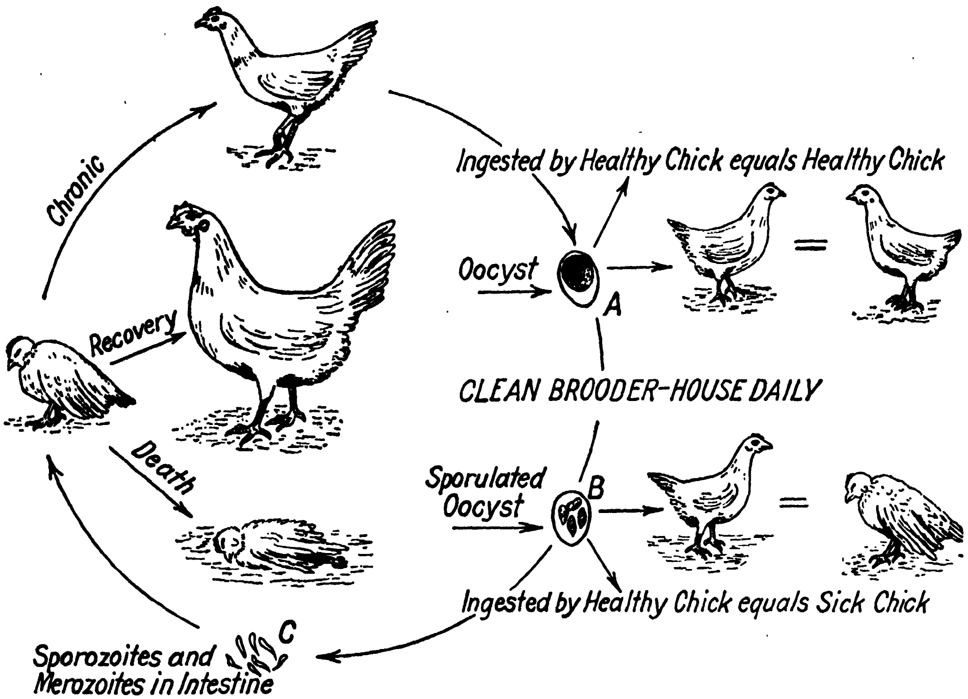

Fig. 150.—The life cycle of the coccidiosis parasite. Under favorable conditions the entire life cycle of the parasite which causes coccidiosis may be completed in from eight to ten days. In the egg stage it gets into the intestinal tract by means of contaminated feed and water. (*Calif. Agr. Exp. Sta.*)

Since the sporulated oocysts constitute the infective stage, and since they are voided with the droppings, it is obvious that any control measures must be directed against the droppings. All feed should be kept as free as possible from contamination by oocysts. Under the roosts and around the watering pan are particularly dangerous sources of infection. It follows, therefore, that the most effective preventive measure is sanitation in the houses and yards.

Infected birds should be promptly removed from the flock. The houses should be cleaned thoroughly and disinfected with lye water near the boiling point. A strong disinfectant must be used because the oocyst is very resistant to most disinfectants. Feed troughs and watering pans

should be placed on wire platforms, and the litter in the house should be kept thoroughly dry. The cultivation of the yards and providing clean range are very necessary.

According to the Connecticut Experiment Station the various treatments that have been recommended as cures for coccidiosis are useful only in so far as they help the bird eliminate the parasites from its system. It is further stated that no drug or remedy is known that will kill the organisms in the cells of the walls of the intestinal tract without causing irreparable damage to the tract. Recently, however, the Wisconsin Experiment Station has secured evidence indicating that a diet containing 2 per cent of flowers of sulfur is of value in preventing and reducing caecal coccidial infection but not as a cure. Apparently not more than

FIG. 151.—Chicks infected with coccidiosis. (*Sawyer and Worley*, 1927.)

2 per cent of flowers of sulfur should be used, or injury may result to the chick's digestive tract. Some evidence was secured indicating that colloidal and organic sulfur are perhaps more efficacious than flowers of sulfur.

Some experimental work has been done demonstrating the possibility of developing a certain degree of immunity against severe coccidiosis by feeding measured suspensions of oocysts to chickens. It is on the basis of such work that the practice is sometimes adopted of raising chickens in uncleaned houses, the theory being that the chicks will develop immunity. Under such conditions there is nearly always bound to be some mortality, in some cases assuming large proportions.

Spirochetosis.—This disease has been observed in some foreign countries and is due to a protozoan organism called *Borrelia gallinarum* (*Spirocheta gallinarum*), which is transmitted from one chicken to another by the tick *Argas persicus.* Infected birds suffer from diarrhea and loss of appetite and soon become pale and droopy, young birds being more susceptible than older ones. Enlargement and degeneration of the liver

takes place. The most effective preventive measure is the eradication of the tick.

Trichomoniasis.—The protozoa *Trichomonas pullorum* is the cause of this highly fatal disease of baby chicks, those over 1 month old having been found resistant. Although the chicks maintain their appetites, their eyes are closed, heads become pale, and wings drag. Sour milk has been reported to be of some value as a remedy.

BACTERIAL DISEASES

Bacteria of various kinds are always present in the intestinal tract of the chicken, some of them apparently being quite harmless, though some give rise to specific bacterial infections.

Botulism.—Also known as "limberneck," the cause of this disease is a highly poisonous substance produced by the microorganism *Clostridium botulinum.* Of the three different types of microorganisms, types A and C produce toxins affecting fowls. The microorganism is apparently quite prevalent in the soil in all parts of the country.

Upon becoming infected, the chicken is soon unable to stand and rests upon the ground with its neck and wing muscles paralyzed. The treatment of infected birds usually proves useless, although epsom salts given in the drinking water at the rate of 1 lb. per 100 birds will serve as a flush. Where botulism occurs in any flock, careful examination should be made of the premises to see if dead animals or other possible sources of contamination exist.

Fowl Cholera.—Fowl cholera is a highly infectious, rapidly fatal disease, caused by *Pasteurella avicida,* a microorganism that multiplies to enormous numbers in the blood and various organs of the body, producing a septicemia, or blood poisoning. The disease is carried by sick or recently recovered birds, by wild birds, persons, other animals, or poultry utensils that have been on infected premises. Cholera spreads rapidly throughout the flock, because the first birds to become infected give off great numbers of the microorganisms in their droppings, and these microorganisms are picked up by the other birds.

The first symptom is a yellowish coloration of the droppings, followed by yellowish, brownish, or greenish diarrhea. An infected bird becomes droopy, feverish, and sleepy and sits with the head drawn down or turned backward, rested in the feathers about the wing. The appetite diminishes, thirst increases, and breathing becomes difficult. Finally the bird is unable to stand, lying with the beak resting on the ground. The comb and wattles often turn a dark bluish red.

During an acute outbreak sickness is seldom noticed more than 24 hr. before death, which usually occurs within 3 days from the time of infection. The disease may destroy the greater part of a flock in a week and

then disappear, or it may linger in a chronic form for months, only occasionally killing a bird. In, the chronic form a continually increasing weakness, loss of weight, paleness of head, and, finally, an exhausting diarrhea are outstanding characteristics. Sometimes the joints of the wings or legs swell, which may break and discharge a creamy or cheesy mass.

A dead bird usually has red spots or hemorrhages on the surface of the heart. The small intestine is congested and hemorrhagic, and the contents consist of a pasty mass. The vessels of the visceral organs may be congested; the liver and spleen enlarged.

Since treatment of affected birds is futile, preventive measures should be undertaken to prevent so far as possible the spread of infection. The first fowls showing acute symptoms should be destroyed and burned. The houses and yards should be thoroughly cleaned at frequent intervals and disinfected with compound solution of cresol in 3 per cent solution or a reliable coal-tar disinfectant in proper dilution. Drinking vessels and feed troughs should be disinfected daily. The protein level of the diet should be reduced at least one-half, and the flock watched carefully for any further evidence of the disease.

Fowl Tuberculosis.—Avian tuberculosis is a chronic infectious disease of great importance not only as a disease of chickens but also because it may be transmitted from chickens to swine. Avian tuberculosis is caused by *Mycobacterium avium,* which may be introduced into a flock by the purchase of infected birds or by wild birds and other animals.

The disease usually progresses slowly so that symptoms are for the most part observable only in birds over one year of age. In advanced stages of the disease there is loss in weight, dullness, dry appearance of the feathers, and diarrhea with greenish or yellowish droppings. On post-mortem examination the liver, spleen, and intestines are covered with yellowish-colored tubercles of varying sizes.

In living fowls tuberculosis may be diagnosed by applying the tuberculin test, as in the case of dairy cattle. A small drop of tuberculin is injected into the skin of one wattle, the other being used as a control. The manner of injecting the tuberculin requires skill and care, and the test should be done only by properly qualified persons. The results of the test should be read 48 hr. after injection, a positive reaction consisting of a doughy swelling of the injected wattle.

Since droppings constitute the greatest source of infection, special precautions should be taken to prevent chickens from coming in contact with droppings of infected birds. All utensils should be carefully protected so that birds cannot get their feet into them. They should be so arranged that they may be disinfected easily. The birds should not be fed on bare land or in filthy houses. There should be no water puddles

or mud holes in the yards, and the birds should not be allowed access to dark, damp places under the farm buildings or elsewhere.

Newly purchased birds should be placed in quarantine for at least 2 weeks before they are allowed to mingle with the flock. A wise precaution would be to purchase birds that have passed the tuberculin test.

Fowl Typhoid.—Fowl typhoid is an infectious disease occurring in adult chickens and is caused by a microorganism called *Salmonella sanguinaria.* It was formerly regarded as of importance to adult birds only but has recently been shown to attack young chicks, sometimes causing heavy losses.

Fowl typhoid may be introduced into a flock by infected birds or infected material, such as shoes and litter. The symptoms in infected chickens include dullness, loss of appetite, and fever, and the droppings are soft and greenish or yellowish in color. The symptoms may be observed 4 to 6 days after the birds become infected. Because the disease is highly infectious, all diseased birds should be removed from the flock immediately, killed, and burned. The healthy birds should be moved to new quarters, if possible, and the houses and equipment should be thoroughly cleaned and disinfected with a 3 per cent cresol compound.

Observations made at the New Jersey and California experiment stations indicate that the disease may be transmitted through the egg.

Vaccination against fowl typhoid is practiced rather extensively in some sections, the vaccine consisting of a suspension of the microorganisms in which their virulence has been reduced or destroyed by heat or by chemicals. It should be observed, however, that birds successfully vaccinated against fowl typhoid will give a positive reaction to the agglutination test for the pullorum disease for as long as 36 days after a single injection of fowl-typhoid vaccine and for as long as 65 days after a double injection of the vaccine.

Omphalitis.—This disease, which is also known as "navel ill," results from the bacterial infection of the navel at about hatching time, several different kinds of microorganisms apparently being involved. The wet form of omphalitis is known as "mushy chick disease" and is associated with infections by certain members of the bacterial genus *Clostridium;* the dry form is associated with nonspecific bacterial infections.

The disease appears during the second or third day after hatching, reaches its height by the sixth, and disappears entirely by the tenth day. The infected chicks appear stunted and groggy.

There appears to be no satisfactory method of treatment. The most effective preventive measure consists of the frequent cleaning and disinfection of the incubators and hatching compartments. The Connecticut Experiment Station recommends disinfecting the incubators between hatches by using 3.5 fluid ounces of commercial formalin, evaporated from

cheesecloth, per 100 cu. ft. of incubator contents at a wet-bulb reading of 90°F.

Pullorum Disease.—The pullorum disease, which frequently causes such enormous losses among chicks, has been called "bacillary white diarrhea." It is caused by a microorganism called *Salmonella pullorum*, which infects the ovary of the hen, although it is also found in the yolk sac and intestinal tract of chicks.

The ovary of an infected hen presents a characteristic appearance. The partially or wholly developed yolks are angular in outline, shrunken,

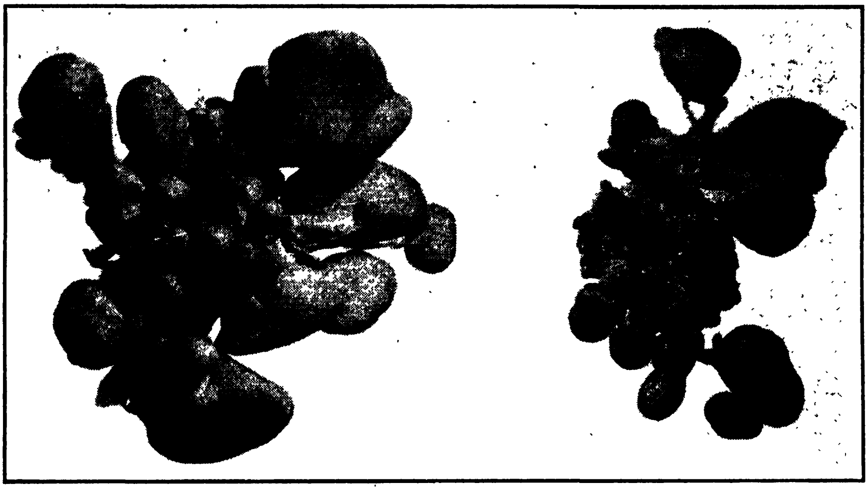

Fig. 152.—Ovaries from two hens that are carriers of the pullorum disease (bacillary white diarrhea). Practically all of the ova are abnormal. (*Edwards and Hull*, 1928.)

hard, and discolored to a dark brown or greenish color. At times, yolks containing dark fluid are present.

Chicks that recover from the disease frequently retain *S. pullorum* in their bodies, where it later localizes in the active ovary. The disease may be contracted also by feeding with fowls that harbor the organism or by eating infected eggs and in some cases from 50 to 70 per cent of a flock of hens may become infected. Many of the eggs laid by these hens carry the microorganism, and chicks hatched from them spread the disease to others.

Nearly all of the exposed chicks become infected, and the death rate may reach 100 per cent. The disease may be transmitted at hatching time if eggs from infected hens are incubated in the same incubator with other eggs. Another source of infection is through incubators and brooders that have previously held diseased chicks. Day-old chicks from infected flocks may carry infection to other chicks.

In the ordinary form of the disease in the adult hen no external symptoms are observed, and it is only through the presence of the disease in the chicks that attention is directed to its presence in the breeding stock.

In baby chicks hatched from infected eggs the symptoms appear immediately after hatching or in a day or so. Chicks that contract the disease after hatching show symptoms 4 to 10 days later, and deaths occur from the time of hatching until about 3 weeks later.

Infected chicks frequently utter squeaky chirps and appear drowsy and ruffled, and the vent is sometimes smeared with fecal discharges.

Not only does pullorum disease cause heavy mortality among infected chicks, but also it has been demonstrated that the disease is responsible

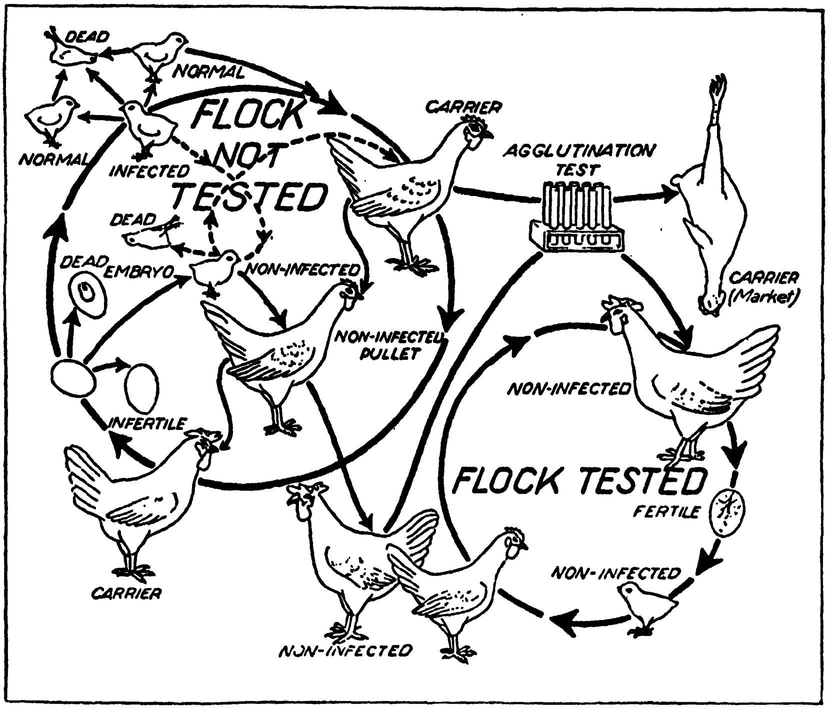

FIG. 153.—Showing the method of dissemination and the means of control of pullorum disease. (*Kans. Agr. Exp. Sta.*)

for lowering hatchability by increasing embryo mortality during incubation. Results have been secured indicating that egg production is lowered when layers are infected with the microorganism causing the disease.

There is no known method of treatment; in fact, the nature of the disease suggests the practical difficulties of devising methods of treatment that could reasonably be expected to be of value.

Controlling Dissemination.—It is possible, however, to carry out practical methods of control which serve the purpose of reducing mortality among chicks to the minimum. The identification of infected hens by a reliable test, their removal from the breeding flocks, the cleaning up and disinfection of the premises, and the disinfection of the incubators

and hatching compartments constitute the minimum measures that must be undertaken to control the dissemination of pullorum disease.

There are three reliable methods of testing, any one of which must be performed by a properly qualified party: (1) the tube-agglutination test, (2) the rapid whole-blood stained-antigen test, (3) the rapid-plate serum test. In performing any one of the three tests certain precautions must be taken with respect to the procedure followed, but lack of space prevents giving the details here. Moreover, all pullorum testing work should be carried on under the immediate supervision of the state livestock sanitary authority or similarily qualified official in each state.

The tube-agglutination and the rapid-plate serum test must be conducted in the laboratory, the sample of blood from each bird being drawn from the bird on the poultry premises and shipped to the laboratory where the "readings" are made. The leg-band numbers of the reacting hens are sent to the flock owner who must go over his flock to remove all reactors.

The rapid whole-blood stained-antigen test is conducted on the poultry premises, the reacting birds being removed immediately after the reading of the blood samples.

As the result of extensive tests conducted by investigators at the Illinois Experiment Station it was concluded that, with properly qualified parties doing the work, the rapid whole-blood stained-antigen test is the simplest and most practical method devised for removing reactors from large numbers of flocks.

All birds over 4 months of age, breeders and other birds, should be tested prior to the breeding season each year, and if there are any reactors the flock should be retested not less than 30 days thereafter. Repeated tests should be performed until all remaining birds give two successive negative tests not more than 4 months apart. All reactors should be removed from the flock upon the completion of the test, and the premises should be thoroughly cleaned and disinfected. Since infected hens may transmit the disease to noninfected hens, the reactors should be removed from the premises as soon as practicable. The testing of the breeding flocks combined with the removal of the reactors and the thorough disinfection of the premises constitutes the most effective way of controlling the dissemination of the disease.

An additional valuable method of controlling it is by fumigating the incubators or hatching compartments 24 hr. before each hatch for the purpose of reducing the spread of infection from infected to noninfected chicks at hatching time. The Illinois Experiment Station has demonstrated that disinfecting forced-draft incubators with formaldehyde gas is effective, one method consisting of hanging formolized cheesecloth in the incubator, and another consisting of mixing formalin with potassium

permanganate. Of course, eggs from nontested flocks should never be incubated in the same incubator or in the same incubator room with eggs from tested flocks, but even where eggs from tested flocks only are being incubated it is sound policy to practice the fumigation of the incubators. The proper fumigation of incubators requires very careful procedure to make sure that the disinfection is efficient. A number of institutions have worked out the proper methods of procedure, among the most complete of which are probably those developed by the Illinois Experiment Station.

Finally, since pullorum infection among baby chicks frequently results in very high mortality, it is wisdom on the part of the purchaser of baby chicks to secure them from flock owners and hatchery operators who carry out a definite system of pullorum testing and sanitary incubation.

Salmonella aertrycke Infection.—This is a highly infectious disease of chicks that frequently proves highly fatal. In the cases that have been reported, chicks from 3 to 10 days of age were affected, the symptoms being much the same as in the case of pullorum infection. Practically nothing seems to be known concerning methods of treatment.

Streptococcic Peritonitis.—This disease is caused by *Streptococcus pyogenes* but is not common in this country. Infected birds exhibit many of the same symptoms as in other diseases: feathers ruffled, eyes partly closed, heads drawn back, yellowish- or brownish-colored feces. The visceral surface of the peritoneum and the ventral surface of the liver are observed to be covered with a fibrinous exudate. No treatment has been devised.

VIRUS DISEASES

Some of the most important diseases affecting chickens are caused by filterable viruses, organisms so small that they cannot be seen even under high-power magnification and pass through filters that retain ordinary types of bacteria.

Epidemic Tremor of Young Chicks.—This disease may occur in chicks at any time during the first 6 weeks but usually manifests itself when the chicks are about 3 weeks old. The first and most noticeable characteristic symptom is a pronounced trembling of the head. The cause of the disease has not been definitely ascertained, and naturally no cure is known. Epidemic tremor appears to be different from congenital tremor in chicks, which is most likely to occur at hatching time and apparently is inherited.

Infectious Bronchitis.—This is a disease caused by a filterable virus which affects principally the respiratory tract of chicks. The symptoms are very similar to those produced by laryngotracheitis, which affects old birds more severely than young ones. For a brief discussion of the

general symptoms, reference should be made to the discussion of the latter disease. It is stated that in infectious bronchitis there is no blood in the respiratory passages, but cheesy matter and mucous material may be found in the bronchial tubes. The mortality among chicks suffering from infectious bronchitis is frequently very high.

Fowl Paralysis.—The term "fowl paralysis" (*Neurolymphomatosis gallinarum*) is frequently used to designate a complex of somewhat related diseases. There is lack of agreement among investigators concerning the causative agent as well as the relationship among the different forms of the disease, which for the present may be termed "neurolymphomatosis," "lymphomatosis," "leukosis," and "sarcoma."

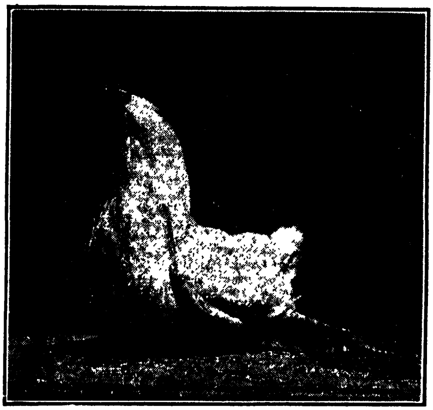

Fig. 154.—A stage of fowl paralysis. (*Pappenheimer, Dunn, and Cone,* 1929.)

Fig. 155.—Fowl paralysis terminal stage, complete prostration. (*Pappenheimer, Dunn, and Cone,* 1929.)

By some investigators neurolymphomatosis is regarded as a transmissible disease characterized by infiltrations and tumorlike formations in the motor nerves, resulting in the paralysis of the muscles controlling motion. Lymphomatosis is pathologically characterized by anemia, hyperplasia of the bone marrow, and large-cell lymphocytic infiltrations of the visceral organs and peripherial nerves. Four types of leukosis have been recognized, leukosis in general being regarded as a disease of the blood and blood-forming organs. Sarcomas are thought not to be related to leukosis.

In view of the present unsettled problem pertaining to this disease complex, it is possible here only to make a few broad generalizations concerning the effects of fowl paralysis on chickens, the term fowl paralysis being used here in a very general sense. The disease usually occurs in chicks between 2 and 9 months of age, although it has been observed at a younger age. Infected birds usually die, the mortality in flocks often exceeding 50 per cent.

The general symptoms include lameness in one or both legs, droopy wings, sometimes grayish color of the iris of the eye, and in advanced cases diarrhea followed by emaciation. Upon microscopic examination of the large nerves, alterations in size, color, and form are noted. The large sciatic nerve frequently shows one of its two divisions very much enlarged. Lesions may be found in the brain and the spinal cord, and tumorlike masses may be present in several of the organs and tissues.

No method of treatment has been worked out, and little can be said regarding preventive measures. Sanitation is of importance, and great

Fig. 156.—One normal and one inflamed nerve in each of 5 pairs of femoral nerves of fowls suffering from fowl paralysis. Note in particular the marked inflammation of one nerve of the third pair. (*Kernohan*, 1936.)

care should be exercised in introducing new stock to make sure that it does not come from an infected flock.

Fowl Plague.—This disease, formerly called "European fowl pest," appeared in the United States for the first time in 1924. It is a very acute, infectious disease which has caused heavy mortality in different parts of Europe since it was first discovered in Italy in 1878. The causative agent of the disease is an ultramicroscopic virus.

The symptoms of chickens affected with European fowl pest include a ruffled condition of the feathers, loss of appetite, droopiness, darkening and swelling of the comb and wattles, and in advanced cases a clogging up of the eyes and nostrils with a sticky exudate. There is usually a wheezing and rattling sound during breathing. Death usually occurs in 2 to 5 days, and, since the disease is so highly infectious, a large part of the flock may die in a relatively short time.

Diseased birds cannot be treated successfully, so that the best the poultryman can do is to prevent its appearance in the flock in so far as possible. This can be accomplished best by avoiding the purchase of stock from places where the disease exists. If the disease does break out, diseased birds should be removed from the flock immediately, and the healthy birds should be moved to new quarters. The diseased birds should be killed and burned, every precaution being taken to avoid spilling any blood on any part of the premises. The houses and equipment should be thoroughly disinfected with a 3 per cent solution of cresol compound. If the disease occurs in birds being shipped to market, all shipping equipment, including coops, crates, and live-poultry cars, should be cleaned and thoroughly disinfected. It is recommended to quarantine the poultry plant where the disease occurs to avoid spreading it to other plants.

Fowl Pox.—Pox nodules on the heads of chickens and yellowish cheesy patches in the mouth and eyes are caused by a virus. Fowl pox is highly infectious. The usual symptoms include pox nodules on the comb, face, ear lobes, and wattles and, in severe cases, cheesy patches in the mouth and throat. Frequently the eyes become closed, and there is difficulty in breathing. Birds affected become dull and weak and lose flesh. The duration of the disease may vary from 3 to 15 days up to several weeks, depending upon the natural resistance of the birds and the conditions under which they are kept, dampness and drafts favoring its spread.

Affected birds should be removed from the flock and placed in a comfortable room unless the disease is in an advance stage, in which case the birds should be killed and burned. Whenever the disease makes its appearance in the flock, the houses, drinking vessels, and feed hoppers should be disinfected thoroughly. Since drinking water is a fertile source of the spread of chicken pox, every precaution should be taken to disinfect water pans.

If treatment of affected birds is decided upon, the following suggestions should be taken: Rub the chicken-pox nodules with a solution of 2 drams of common salt dissolved in 1 qt. of warm water; remove the nodules; and apply tincture of iodine or a 5 per cent solution of carbolic acid to the diseased surface. Wash the eyes and inject the nostrils with a solution of 2 drams of permanganate of potash in 1 pt. of water or a solution made up to 1½ oz. of boric acid and 1 oz. of powdered borax (borate of soda) dissolved in 1 qt. of water, applied warm.

Vaccination Successful.—Since fowl pox sometimes results in high mortality but more frequently causes a great decrease in egg production, usually in the fall or winter months of the year when egg prices are relatively high, it is most important for poultry raisers to recognize that there

is a very practical and efficient way of avoiding an outbreak of the disease in the laying flock. It should be observed, however, that where no trouble from fowl pox has been experienced there is rarely any occasion for vaccinating.

Three principal types of vaccines are being used to induce immunity against the disease: fowl-pox vaccine, pigeon-pox vaccine, and anti-diphtherin. Pox vaccine is prepared by making a 1 per cent suspension of the powdered virus in sterile distilled water and adding 10 per cent of glycerin. This vaccine is usually preferred, although pigeon-box vaccine produces a milder reaction, which usually does not last so long. The "stick" method and the "feather-follicle" method are the two methods used in vaccinating. In the stick method the skin of the leg or undersurface of the wing is pricked with the point of a sharp knife which has been dipped in the vaccine suspension, the blade being allowed to penetrate to a depth of ⅛ in. only. The feather-follicle method consists of first plucking about seven feathers from an area on the leg and then applying the vaccine suspension with a stiff brush or swab. A "take" indicates successful vaccination: in the stick method a scab forming over a local swelling, and in the feather-follicle method a small scab appearing over each swollen and inflamed feather follicle.

FIG. 157.—Vaccination on leg, 18 days after vaccine had been applied by piercing the skin in two places with a very sharp pointed dissecting needle, which had been dipped in vaccine. (*Western Wash. Exp. Sta.*)

Probably the best time to vaccinate is about 2 months before the pullets are to be put in the laying houses. Pigeon-pox vaccine is less liable to cause a setback than fowl-pox vaccine, but at least 15 feathers should be plucked to insure successful vaccination.

Laryngotracheitis.—This disease is due to a filterable virus which causes a considerable degree of respiratory distress and in many cases is highly fatal. It has often been called "infectious bronchitis," but according to the New Jersey Experiment Station infectious bronchitis is a different disease in that it causes heavier mortality in chicks and the symptoms exhibited are different from those exhibited by laryngotracheitis.

During recent years very heavy mortality in thousands of flocks has resulted from laryngotracheitis infection. Chickens are highly susceptible, the severity of attack and the mortality being greater in adult than in young stock. The external symptoms are first "watery eyes," followed by sneezing and coughing. As the disease progresses, the bird begins to sit with its eyes closed, breathing becomes heavier and wheezy as the result of an exudate which accumulates in the larynx and trachea, and bloody mucus or clotted blood may be expelled. The disease usually runs its course in 7 to 15 days, many birds succumbing, and others recovering to act as carriers of the virus.

Upon examination internally, the throat and larynx are usually found to be swollen and inflamed, bloody exudate adhering to the walls of the trachea, and hemorrhages appearing in the lining of the larynx and trachea.

Apparently no satisfactory method of treatment has been devised, although in some cases it has been found that raising the temperature and humidity of the air in the house gave some relief from distress. In case the disease appears in a flock all birds should be killed and burned immediately. Incubators, appliances, utensils, houses, and premises should be thoroughly cleaned and disinfected. The houses should be left vacant for at least 2 months. New stock should be secured from sources where there has been no infection.

Vaccination against laryngotracheitis has been tried at several institutions until finally the New Jersey and California experiment stations developed the cloacal and bursal methods of vaccinating. The cloacal method consists of direct swabbing of the vaccine on the lining of the cloaca and the bursa Fabricü, a blind sac connected with an opening into the wall of the cloaca. The vaccine used was made of the dried tracheal exudate obtained from infected birds, suspended in 50 per cent glycerin. The intrabursal method consists of injecting virus into the cavity of the bursa Fabricü with a 16 to 20 gage blunt-pointed, slightly curved hypodermic needle. The vaccine used was obtained by using a 1:500 dilution of dessicated virus which produced infection when 0.1 cc. of 1:5,000 or 1:10,000 dilution was injected. The best age for vaccination appears to be between 2 and 4 months.

A successful vaccination is indicated by a take, which means that the mucous lining of the cloaca and bursa Fabricii become inflamed in about 5 to 7 days. If no inflamation has developed at the end of 5 days the bird should be revaccinated, for the simple reason that practically 100 per cent takes is necessary, or there may be loss from mortality among birds that did not take but later become infected by the birds that were successfully vaccinated. Vaccination should be performed only by properly qualified persons.

FUNGUS DISEASES

There are three fungus diseases affecting chickens, each caused by a different fungus.

Aspergillosis, or Brooder Pneumonia.—Heavy losses in chicks sometimes result from aspergillosis, or brooder pneumonia, a fungus disease of the lungs and air sacs. The causative agent is *Aspergillus fumigatus*, the growth of which is favored by warmth and moisture.

The fungus can pass through eggshells, and it is believed that some outbreaks in brooder chicks may be due to infected eggs that have been in contact with moldy material. More frequently the disease is due to chicks or older birds' scratching in moldy hay or straw.

In advanced cases of the disease the birds become listless, breathing becomes difficult, fever develops, the wings droop, and there is diarrhea. In young chicks death usually occurs within a few days, although older birds may live for a few weeks after the appearance of symptoms.

On post-mortem appearance, the walls of the windpipe, the air passages in the lungs, and the air sacs in the abdominal cavity show whitish or yellowish nodules.

In order to prevent an outbreak of the disease, sanitation is necessary: Provide clean litter, and keep the houses and yards clean at all times. If the disease appears, clean and thoroughly disinfect the house and premises.

Favus.—This is a contagious disease commonly known as "white comb" because of the formation of grayish white spots on the comb, ear lobes, and wattles. The causative agent is a fungus called *Lophophyton gallinae.*

Since favus can be transmitted to man, care should be taken to avoid getting the fungus into cuts and wounds of the hands and face. The Wisconsin Experiment Station demonstrated that favus in chickens could be cured easily by one application of formaldehyde and vaseline. The desired quantity of vaseline is melted in a tightly sealed jar in hot water. Then 5 per cent by weight of commercial formaldehyde is added to the melted vaseline, and the jar tightly sealed and shaken until the vaseline hardens.

Thrush.—This disease of young chicks is caused by the yeastlike fungus *Monilia albivans*, the characteristic symptoms including whitish ulcers in the crop, brownish deposits in the proventriculus, and ulcers in the gizzard. No satisfactory treatment is known.

DISEASES OF UNKNOWN ORIGIN

There are certain diseases not already discussed that have been a serious menace to the poultry industry for years but for which no specific

causative organism has been identified. There are certain other newer diseases of relatively less importance the causative agent of which has not yet been determined.

Coryza.—The terms "colds," "coryza," "catarrh," and "roup" have all been used more or less interchangeably by poultrymen in referring to any inflammation of the mucous membranes of the upper respiratory tract. Coryza, however, is the proper designation for an infectious cold, this infection having been found in association with the bacterial organism *Hemophilus gallinarum.*

The mildest form of the disease occurs as a simple coryza with a nasal discharge which may be of relatively short duration or may persist for some time. In the more severe types of the disease, the coryza is complicated by other manifestations, including swelling of the face; inflammation of the sinuses, trachea, and bronchial tubes; infection of the air sacs; gasping; and coughing. The discharge from the nostrils may develop into cheesy matter. The duration of the disease naturally depends upon its severity and the extent of the complications. Chicks and adults are susceptible. In addition to the loss from mortality, there is also slowing up of growth, wasting away of flesh, and decreased egg production in the case of laying stock.

FIG. 158.—Showing method of relieving stoppage of the tear duct, commonly called "cold" in the eye. (*Beach and Freeborn*, 1927.)

Damp, dirty, and drafty houses seem to be conducive to the spread of the disease. In case of an outbreak, the poultry house should be cleaned and disinfected thoroughly. The feeding utensils and drinking vessels should be cleaned and scalded daily with water containing 3 per cent of liquor cresolis compositus or other effective antiseptic.

If treatment is resorted to, either of the following methods may be tried: (1) a hypodermic injection of 1 to 2 cc. of fresh 15 per cent argyrol directly into the cavity of the sinus, care being necessary not to injure the eye or inject the tissues; (2) alternate use of a 4 per cent solution of boric acid and a mixture composed of 5 grains of carbolic acid, 10 grains of menthol, and 1 oz. of liquid petrolatum, injected into the nasal passage two or three times daily.

Cloacitis.—As the name suggests, in this disease there is an inflammation of the cloaca and vent. By poultrymen the disease has often been called "vent gleet" and is noted for its very offensive odor. The causa-

tive agent has apparently not been identified, but the following treatment has been found to give satisfactory results in the majority of cases: Wash the vent and cloaca three or four times with a 3 per cent solution of chromic acid.

Salpingitis.—In this disease there is inflammation of the oviduct, with a resultant discharge which irritates the vent and smears the feathers below it. The causative organism has not been isolated. Affected birds should be isolated and treated as follows: Using a blunt-nosed, hard-rubber syringe, wash the cloaca and lower part of the oviduct with warm salt water in the proportions of 2 teaspoonfulls of salt to 1 qt. of warm water.

Tumors.—Tumors and tumorlike growths have long since been of considerable economic importance because of their effect on mortality and egg production. They are far more common in adult than in young stock and more common in birds over 2 years old than in yearlings. They are constituted of masses of new tissue, the growth of which is apparently not controlled by the regulatory system that controls the growth of other body tissues. As the result, tumors may be of considerable size.

The ovary seems to be a favorite seat of infection, and indications are that mortality from ovarian tumors has been on the increase during recent years. Tumors may grow in almost any part of the body, there being tumors of the bone, muscle, and other tissues. They are classified as benign and malignant, benign tumors being those that increase in size by central growth and are not invasive, whereas malignant tumors invade and replace the tissue surrounding their place of origin. Malignant tumors of epithelial origin are called "carcinomas," and those originating in connective tissue are called "sarcomas." The growth of malignant tumors may involve several structures, but benign tumors do not spread from one organ to another.

The cause of tumors, which are also sometimes referred to as "neoplasms," is apparently not known, and no satisfactory treatments have been devised. Poultry breeders, however, in selecting their breeding stock would do well to discard all birds belonging to families any members of which have been known to have tumors, and the parents of their families should likewise be discarded.

Vesicular Dermatitis.—This comparatively new disease, the causative organism of which has not been identified, has been observed to occur most frequently in chickens less than a month old that have been raised on virgin sod in eastern Colorado. Because of this it is often referred to as "sod disease."

The mortality is sometimes very high, the general symptoms including the formation of blisters between the toes and swollen feet, the blisters being replaced by scabs which leave the toes greatly distorted. The disease is easily prevented by raising chickens on land that has been plowed.

POISONS

Mortality or sickness from poisoning often occurs when chickens eat poisonous plants, seeds, or other materials gleaned from the fields or are fed certain feeds or other materials that have toxic properties.

In the chapters on feeding practice a list of poisonous plants and seeds was given. Normal diets or commercial feed mixtures rarely poison chickens.

The poisonous effects of selenium have been demonstrated in the feeding of grains grown on certain types of alkali soils in South Dakota and adjacent regions; this subject has been discussed in the chapter on incubation principles and practice.

Rose chafers are poisonous to chicks up to 10 weeks of age, 15 or 20 chafers being sufficient to kill a week-old chick.

Occasionally chickens encounter drugs or chemicals that are poisonous, *e.g.*, arsenic used for the poisoning of rats and grasshoppers, kamala in excessive amounts, lead contained in paint skins, nicotine sulfate in excessive amounts, phosphorus contained in rat poisons if consumed in considerable quantities, and potassium permanganate if consumed in any appreciable quantity.

Rarely does the addition of antiseptics to the drinking water serve any useful purpose as a cure in cases of poisoning.

DISINFECTANTS AND THEIR USE

A disinfectant is a substance that is capable of killing microorganisms in the forms in which they usually occur in poultry premises, and in order to qualify as a complete disinfectant it must be able to kill the more resistant spore forms of different diseases as well.

The need for disinfecting feeding and watering utensils, equipment, and poultry houses is far more urgent than most poultrymen appreciate. Most diseases encountered in hatcheries and on poultry plants are filth borne; *i.e.*, they spread much more rapidly in a place that is filthy than in a place that is kept reasonably clean.

Sanitation in incubators and on poultry plants is the most effective way of combating losses from mortality because it keeps the spread of disease to the minimum. A reasonable degree of sanitation can be maintained only through the judicious use of efficient disinfectants, of which there are on the market a number that can be secured at reasonable cost.

The efficiency of a disinfectant is determined in large measure by the extent to which it comes into direct contact with the microorganisms. The accumulation of filth allows millions of the microorganisms to be inaccessible to the disinfectant, and as a result little is accomplished. All

objects that are to be disinfected should be cleaned thoroughly before the disinfectant is applied. Many poultrymen, however, have very hazy notions concerning what constitutes proper cleansing.

The suggestion is offered here that when the average poultryman cleans his poultry house as he ordinarily cleans it, he could then scrape the floor and gather up several shovelfuls of filth, which contains millions of disease organisms. In fact, if the average poultryman cleans his laying house two or three times in succession, he will usually still find some dirt left in cracks and crevices and on the floor. The floor should be washed thoroughly with water, under pressure if possible.

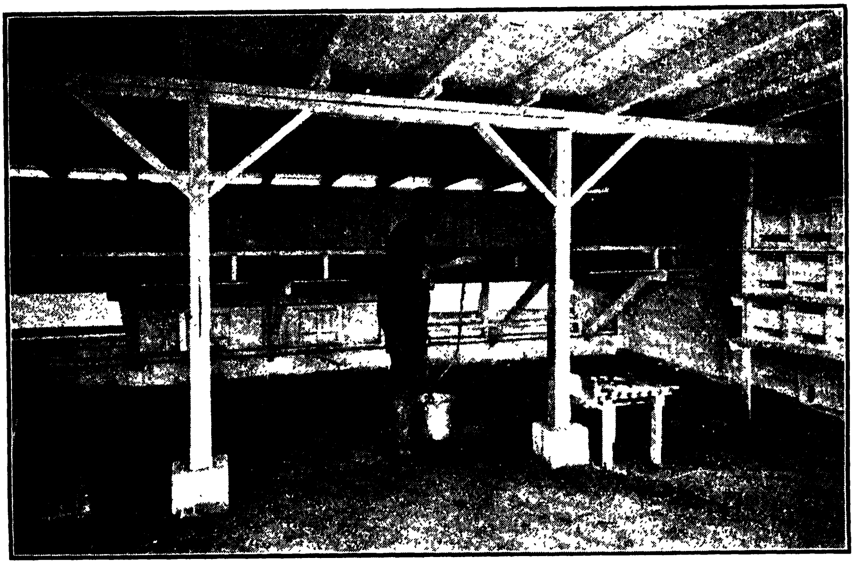

Fig. 159.—The proper cleaning and disinfection of the poultry house means that the floor, walls, and ceiling be cleaned most thoroughly and then disinfected thoroughly. (*U. S. Dept. Agr.*)

The most effective means of combating parasites and diseases is to prevent their occurrence in so far as possible. Prevention rather than cure should be the watchword of every poultryman. Prevention implies sanitation through adequate cleansing and proper disinfection.

Bichloride of Mercury.—Applied to clean surfaces, bichloride of mercury is an effective disinfectant but is corrosive to metals and irritating to wounds.

Carbolic Acid, or Phenol.—In a 5 per cent solution, carbolic acid is an efficient disinfectant though somewhat more expensive than some others.

Chlorinated Lime, or Calcium Hyperchlorite.—A 5 per cent solution, or 6-oz.-per-gallon of water, is efficient as a disinfectant and is a deodorizer.

Creolin.—A 4 or 5 per cent solution is used for disinfecting.

Cresol.—A 2 or 3 per cent solution, or 1 qt. of creolin thoroughly mixed with 12 gal. of warm soft water, makes an efficient disinfectant, provided the cresol used contains at least 90 per cent of cresylic acid.

Formalin, or Formaldehyde.—Formalin is a 40 per cent solution of formaldehyde, an 8 to 10 per cent solution of which makes a strong disinfectant but is irritating to the skin and especially the eyes, which should be protected. Formalin should be kept in tightly sealed containers.

Liquor Creosolis Compositus, or Compound Solution of Cresol.—This disinfectant is composed of equal parts of cresol (U.S.P.) and linseed-oil-potash soap and is used in a 3.5 to 4.0 per cent solution, or about 1 qt. of the mixture per 7 gal. of water.

Sodium Hydroxide, or Lye.—In a 2 per cent solution, or 1 lb. per 6 gal. of water, this is a cheap and efficient disinfectant, but care should be taken to avoid getting it in the eyes or on the face. A good whitewash is made with water, 1 per cent of sodium hydroxide, and at least 5 per cent of good water-slaked or hydrated lime; but such a whitewash injures paint and varnish.

Sodium Hypochlorite.—A 5 per cent solution makes a satisfactory disinfectant.

Sodium Orthophenylphenate.—A 1 per cent solution is an efficient disinfectant if applied at a temperature of 60°F. or above.

DRUGS

Curing sick chickens is a very poor substitute for the prevention of disease. Moreover, attempting to cure sick chickens has several disadvantages. In many cases the individual bird is not worth the time, trouble, and cost of the remedy involved in the treatment. Then, again, even if a sick bird is "cured" it may serve to spread disease while and after being treated. In the third place, what few cures are effective tend to minimize in the minds of poultrymen the necessity of maintaining proper preventive measures.

There are comparatively few drugs that can be used justifiably in conjunction with daily poultry-husbandry practices, although there are cases when the administration of a drug may be justified on the grounds of providing temporary relief or in treating valuable birds. Some drugs are used as antiseptics, which tend to inhibit or prevent the growth of microorganisms without necessarily destroying them. The use of so-called tonics and conditioners should be condemned, for the simple reason that for the most part they are practically worthless.

Argyrol.—A 5 to 20 per cent solution is sometimes used as an antiseptic for treating the eyes and nose when inflamed.

Boric Acid.—A solution of 5 parts boric acid to 100 parts water may also be used as an antiseptic for inflamed eyes.

Carbon Tetrachloride.—This drug in gelatin capsules at the rate of 1 cc. per capsule for a mature chicken is sometimes given as a vermifuge for roundworms.

Derris Root.—A dusting powder containing 20 per cent of powdered derris root or a dip made up of ¼ oz. of the powder per gallon of water is effective against chicken lice.

Epsom Salts, or Magnesium Sulfate.—Sometimes used as a physic but should be used with caution. The chickens are deprived of water for part of the morning, and then for every 100 birds 1 lb. of epsom salts is dissolved in about 2 gal. of water.

Ferric Chloride.—In tincture form is used for dressing wounds.

Iodine.—In tincture form is also used for dressing wounds.

Iodoform.—Contains about 96 per cent iodine and is sometimes used with boric acid as a dusting powder for wounds.

Mercurial Ointment.—Diluted with about equal parts of vaseline is used to kill lice, a small amount being spread under the vent and under the wings, although it should not be used on breeding stock.

Naphthalene.—When mixed with twice its weight of vaseline, naphthalene may be used as an ointment spread around the base of the tail to kill the northern fowl mite.

Nicotine Sulfate.—This is an extremely poisonous drug available on the market as a solution containing 40 per cent of nicotine. It is very effective against lice and is applied to the upper surfaces of roosts just before the chickens go to roost, about 8 oz. being used to paint every 100 ft. of roosts. A second application in about 9 days is necessary to kill the lice that hatch after the first application.

Sodium Fluoride.—Used as a dusting powder against lice or as a dip, in the proportion of 1 oz. per gallon of warm water. It is poisonous and an irritant to the eyes.

Tetrachlorethylene.—Has properties similar to carbon tetrachloride.

Tobacco.—Tobacco dust is somewhat effective against roundworms and is used in the mash mixture. The method of feeding it is discussed in the section dealing with the control of large intestinal roundworms.

THE PROBLEM OF DISEASE PREVENTION

The problem of disease prevention is a challenge to every poultryman in the country. There is probably a large element of truth in the suggestion that those poultrymen who engage in sound practices of flock and hatchery management need have little concern over excessive losses from mortality. Paradoxical as it may seem, the greatest mortality often occurs in those flocks where the owners accept disease as a matter of course and temporize with disease by trying to cure sick chickens.

The previous sections of this chapter have dealt with the nature of the various diseases affecting chickens, their causes and "cures" in so far as they have been determined, and specific suggestions concerning the most logical methods of preventing disease from making its appearance. Rigid sanitation through frequent cleaning and proper disinfection is the first requisite in the prevention of disease. Maintaining sanitary quarters involves far more than the average poultryman realizes. The lack of sanitation is not the only factor, however, that contributes to the excessive mortality that occurs every year. Perhaps more poultrymen would become more "disease-prevention" minded by reviewing the factors responsible for the industry's present sad plight. Some of these factors are listed below.

1. In thousands of cases growing chicks and laying hens are kept on the same land year after year, the soil all the time becoming more thoroughly contaminated with the "eggs" of numerous parasites and the organisms of various diseases.

2. Thousands upon thousands of brooder and laying houses are never properly cleaned or thoroughly disinfected.

3. In all too many cases unhealthy conditions, including overcrowding, that tend to lower the vitality of stock, prevail in brooder and laying houses because of poor housing conditions or because of mismanagement or both.

4. On far too many farms the old stock is allowed to mix with the growing chicks.

5. On many farms turkeys are allowed to mix with the chickens.

6. Immature and undersized birds are used all too numerously for breeding purposes.

7. The use of diseased birds as breeders tends to disseminate disease, and inasmuch as more birds become infected each year the dissemination of disease increases each succeeding year.

8. Commercial incubation is frequently a means of spreading disease.

9. The dissemination of disease is augmented by the widespread distribution of baby chicks, market poultry, and breeding stock.

10. In many cases when breeding stock is purchased it is not adequately quarantined before being introduced into the flock.

11. Oftentimes birds shipped from egg-laying contests and poultry shows harbor disease organisms of various kinds.

12. Visitors may carry disease organisms from farm to farm, and the flock owner himself may carry them from pen to pen.

Finally, it is to be observed that with the ever increasing spread of disease, the soil, the water, and even the air become more thoroughly contaminated so that more birds become infested with parasites and infected with disease to cause still more widespread dissemination of

parasites and diseases of various kinds. With such a vicious circle, there is little wonder that mortality is so high.

With a view toward breaking the circle in order to lower mortality, many poultrymen make a practice of drugging their chickens and providing them with antiseptics in the drinking water or condiments in the feed. To administer drugs is rarely justified. Treating drinking water with a satisfactory antiseptic may tend to prevent disease from spreading from one fowl to another, but it is highly probable that very few drug preparations have any therapeutic value whatsoever, for the simple reason that when the preparation comes in contact with the food in the crop the properties of the preparation are rendered inert. Many tonics and conditioners on the market are quite worthless. Furthermore, there is still entirely too much misbranding of poultry remedies.

Where disease breaks out, rather than conducting a post-mortem examination himself, the flock owner should consult a properly qualified veterinarian or public official. If the situation is serious, a few live specimens should be taken or shipped to the veterinary department of the state college of agriculture or to the state livestock sanitary service, and the advice of properly qualified officials should be sought in handling the flock.

The 12 factors enumerated above perhaps present the "problem" of disease prevention that confronts the poultryman of today. At present he is paying the price of negligence in one or more respects. It is rarely the chicken's fault if it gets sick. Moreover, parasites and diseases are not solely to be blamed if they are permitted to destroy birds and cause retarded growth, poor fleshing, and decreased egg production. Clearly the major responsibility for preventing disease from appearing in the flock rests upon the poultryman.

Since parasite eggs and disease organisms are lurking everywhere, in the soil, in puddles of water, in cracks and crevices, and on utensils and equipment, it is obvious that chickens must be hardy and possess strong constitutions to withstand the constant attacks of the enemy. The five lines of natural defense, mentioned in the fore part of this chapter, with which chickens are endowed for the purpose of combating the invasions of parasites and disease organisms must be fortified by a good inheritance. There is need for the development of disease-resistant strains of chickens. A program of selection and breeding based upon the viability of the progeny should be very much worth while. The development of disease-resistant strains, if such be a possibility, and their subsequent distribution would undoubtedly require considerable time so that something should be done in the meantime to reduce the enormous losses from mortality that occur annually. The best hope of accomplishing this would seem to be the adoption of a practical program of *disease prevention.*

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CHAPTER XI

EGG-MARKETING PROBLEMS

The problem of most wisely and efficiently disposing of the enormous number of eggs produced each year is one of vital interest to producers because egg prices and profits in egg production are involved. The first requisite in the marketing of eggs to best advantage is the production of eggs of the highest possible quality. The second requisite on the part of the producer is to take every possible precaution to maintain the original quality of the fresh-laid egg. Then from the time the eggs leave the producing plant until they reach the consumer's table they must be given the best possible care to maintain in so far as possible the original quality. Buyers and sellers of eggs, including wholesalers and retailers, are interested in the various factors of processing and distributing that affect egg quality, for the simple reason that there is less wastage in marketing eggs of good quality than in marketing those of poor quality. Consumers want eggs of good quality or, in many cases, none at all.

The annual egg crop is disposed of in two principal ways: (1) market eggs for human consumption and (2) hatching eggs for the reproduction of the flocks. Eggs inedible as human food are used in the preparation of certain animal feeds; for certain industrial purposes, such as the tanning of leather, the manufacture of textile dyes, printing inks, and photographic films; and in the making of fertilizer. In addition, all too high a proportion of each year's egg crop is lost through breakage and from other causes.

QUALITY IN MARKET EGGS

The term "quality" when applied to market eggs means that condition of shell and contents of eggs which can be marketed in such a manner as to give the greatest satisfaction to the consumer. There are many factors that affect the condition of the shell and egg contents, including the kind of stock and the methods of feeding, storing, and handling, the ultimate quality determining to a considerable degree consumer demand and prices paid.

Market eggs reach the consumer in three principal forms: (1) in the shell, (2) as frozen eggs, and (3) as dried eggs. Shell eggs reaching the consumer may be classed according to whether they have been refrigerated or have been sold without being refrigerated. Frozen eggs reach the consumer in the form of frozen whole eggs, frozen plain yolks, frozen

	Shell eggs		Frozen egg products						Dried egg products		
Per cent of total ⟶	86.73	4.97	6.77						1.53		
Uses	Fresh and storage	Inedible and waste	Mixed or whole	Whites	Plain yolk	Salt yolk	Sugar yolk	Glycerine yolk	Mixed or whole	Albumen or whites	Yolk
Human food uses											
Dining table: home and public eating places	*	..	‡	‡	†	..	¶	..	‡		
Bakery products	†	..	*	*	§	..	*	*	*	‖	§
Candies, confections, marshmallows	‡	..	..	‖	..	..	..	..	..	*	‡
Mayonnaise	..	..	..	..	§	*	‖	¶	†	..	†
Salad dressing	..	..	†	..	‖	§	†	†			
Noodles, macaroni	..	..	†	..	‖	..	..	..	†	..	¶
Ice cream, frozen custards, ices	‡	..	†	†	†	..	‖	..	†	..	§
Food beverages and food beverage powders	‡	..	‡	‡	‡	..	‡	..	†	..	†
Prepared meringue and whipping powders	..	..	..	..	..	..	..	..	..	‖	
Prepared puddings	..	..	..	..	..	..	..	..	†	..	†
Prepared flours	..	..	..	..	..	..	..	..	‖	†	‖
Baking powder	..	..	..	..	..	..	..	..	..	‡	
Sausage manufacturing	..	..	‡								
Animal food uses											
Dog food	..	..	..	..	..	..	..	..	†	..	‡
Bird food	..	..	..	..	..	..	..	..	†	..	‡
Fish food	..	..	..	..	..	..	..	..	..	‡	
Fox food	..	‡	..	..	..	..	..	..	‡		
Hog food	..	‡									
Commercial feeds	..	..	..	..	..	..	..	..	‡		
Technical uses											
Leather and fur trade	..	¶	..	..	..	..	..	..	..	†	‡
Lithographing	‡	..	..	..	..	..	..	..	..	†	
Photo-engraving	‡	..	..	..	..	..	..	..	..	‡	
Cementing cork to jar and bottle caps	..	..	..	..	..	..	..	..	..	†	
Pharmaceuticals	..	..	..	‡	‡	..	..	..	..	†	
Textile printing	..	..	..	..	..	..	..	..	..	¶	
Paints for artistic work	..	..	..	..	..	..	..	..	..	‡	
Printing ink	..	..	..	..	..	..	..	..	..	‡	
Photography	..	..	..	..	..	..	..	..	..	‡	
Gilding books, leather, cloth, and fabrikoid	..	..	..	..	..	..	..	..	..	‡	
Egg shampoo	‡	..	..	..	..	..	..	..	‡		
Loss or waste											
Rots, broken, etc., not recovered	..	*									
Flock reproduction (fresh eggs)											
Commercial hatching	†										
Farm hatching	†										

* 50 per cent or more.
† 1 to 49.9 per cent.
‡ Under 1 per cent.
§ 25 to 49.9 per cent.
‖ 10 to 24.9 per cent.
¶ 5 to 9.9 per cent.

FIG. 160.—Uses for eggs in the United States, estimates for 1935. (*U. S. Dept. Agr.*)

sugared yolks, and frozen whites. Dried eggs reach the consumer as dried whole eggs, dried yolks, and dried whites or albumen. Regardless of the form in which market eggs ultimately reach the consumer, the quality of the final product is determined to a large extent by the original quality of the fresh-laid egg plus the methods of storing and handling to which it has been subjected.

The structure and formation of the eggs and the influence of breeding and feeding on egg quality have been discussed at some length in preceding chapters. It has been pointed out that, in general, breeding seems to influence egg quality to a greater extent than feeding. The quality of the shell, the per cent of thick to thin white, and to some extent the color of the yolk are influenced by breeding. The kind of diet has a marked influence on the color of the yolk and the vitamin content of eggs but little influence on most of the other properties of eggs. The diet may have a pronounced effect on the odor and flavor of eggs.

Quality Shown by Breaking.—Dealers in eggs resort to candling for the purpose of grading eggs according to quality, but housewives judge the quality of eggs by their appearance upon being broken open. Since ordinary candling methods have their limitations in conducting research on factors affecting egg quality, the practice of breaking eggs in experimental work has increased considerably during recent years. Two of the most widely used methods of measuring egg quality include what are known as the "yolk index" and the "albumen index."

When a normal fresh egg is broken open on to a plate the yolk stands up well, the thick white closely surrounds the yolk and also stands up well, and the thin white spreads out over a portion of the plate. For a discussion of the structure of the egg, including two layers of thin white, Chap. II should be consulted. When a stale egg is broken open the yolk appears quite flattened, the thick white has decreased in volume and shows a very flattened appearance, and the thin white is so watery that it covers the entire plate. Between these extremes are many gradations of change in the condition of the yolk and egg white.

The breaking of eggs gives an accurate picture of yolk color, which is greatly influenced by the kind of pigments contained in the diet, as pointed out in the chapter on Feeding Practice. As a basis for comparing color changes in yolks as influenced by diet and other factors, yolk-color standards have been devised, *e.g.*, the yolk-color rotor developed at the Washington Experiment Station. Although the diet may have a pronounced effect on yolk color, work at the National Agricultural Research Center has shown that the change in color resulting from altering the pigments in the diet is more highly correlated with the number of eggs produced than with the number of days elapsing following the alteration in the diet.

The *yolk index* most commonly used is the one first adopted by research workers at Cornell University. The yolk is separated from the white and is measured for its height and width, the former divided by the latter giving the yolk index. Other measures of yolk quality that have been devised include an apparatus for measuring the amount of internal pressure necessary to rupture the yolk and a method of determining the breaking strength of the vitelline membrane which surrounds the yolk. Much more research work is necessary, however, before the extent to which yolk index may be used as a criterion of egg quality can be determined definitely, although it has been shown that yolks tend to become more flaccid and the vitelline membrane weaker as the deterioriation of eggs progresses.

The *albumen index* originally developed is based upon the proportion of thick and thin whites in the egg. The method for separating thick and thin whites was apparently developed at the California Experiment Station and was later modified somewhat at other institutions, since it involves passing a portion of the egg white through a sieve, thus possibly altering its structure as it existed in the egg. Another kind of albumen index was developed at Cornell University and consisted of measuring broken-out whites and comparing them with a set of photographic standards, in which the score of 1 was given for eggs in which the thick white stood up firmly around the yolk and a score of 5 for eggs in which no thick white was apparent. Still another albumen-index method was devised at the Washington Experiment Station which involves measuring the thick white on the plateau of the proximal end of the greatest surface having the least curvature when the white is resting on a flat surface, then measuring the diameter of the thick white at two points at right angles to each other. The albumen index is obtained by dividing the height by the mean diameter. These indexes have been shown to be correlated with the quality of the white of the egg.

The *viscosity index* as a measure of egg quality has recently been developed at the Iowa Experiment Station and involves the use of a torsium pendulum so designed that the damping effects of the unbroken egg can be determined. This index was found to be significantly correlated with yolk shadow and yolk movement.

Size and Shape.—The standard size of market eggs is 2 oz. per egg, and in many respects the more nearly a given dozen approaches standard size of 24 oz. per dozen the higher the price commanded, other things being equal. Eggs averaging larger than 24 oz. per dozen may command more than eggs weighing 24 oz. per dozen, but extra-large eggs are discriminated against because of danger from breakage. Each dozen or case of eggs should be reasonably uniform in size in order to command the best price.

The factor of uniformity of egg shape is of some importance, and extremely long eggs are discounted because of danger from breakage.

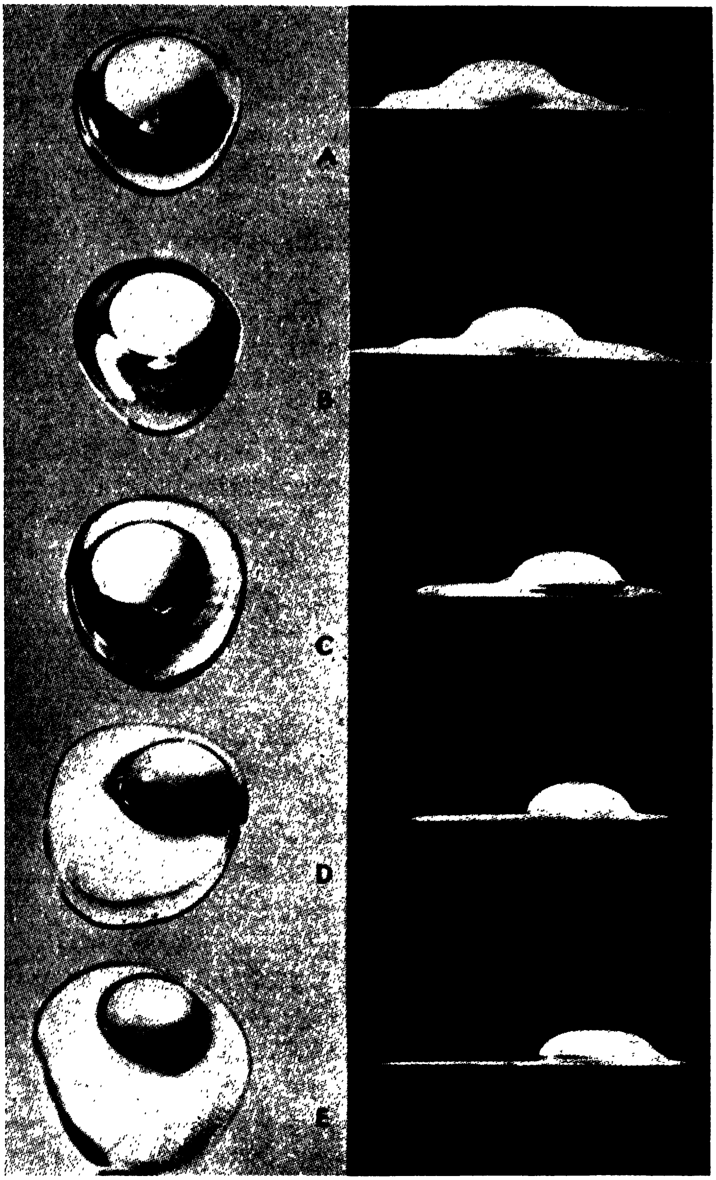

FIG. 161.—The breaking of eggs provides for more accurate judging of interior quality than candling. The eggs shown here exhibit gradations in quality from *A*, where the yolk and white stand up well, to *E*, where the yolk is flaccid and the white watery. (*Heiman and Wilhelm*, 1937.)

Shell Color and Texture.—In most markets there is neither a preference for brown nor a preference for white eggs, but in all markets it is important that a dozen or a case of eggs be uniform in color. In the

case of white eggs it is especially important that the eggs be free of tints. New York City enjoys the reputation of being a white-egg market, although in the last few years brown eggs have been known to top the market at different times. Boston has always had the reputation of being a brown-egg market.

The shell of a market egg should be smooth and even in texture, and this is primarily a matter of selection and breeding. Shells should be spotlessly clean, and each lot of eggs should be as uniform as possible in color and texture.

Determination of Internal Condition by Candling.—The only practicable method of determining the condition of the interior of an egg is by passing a light through the egg. Candling devices include electric, gas, oil, or gasoline lights, by far the most commonly used being electric lights. Candling for the most part is done in dark rooms, which should be kept thoroughly clean and well ventilated.

The contents of an egg are observed by placing the egg between the light and the eye of the observer with the egg about 1 ft. below and about 1 ft. in front of the eye. The large end of the egg is held up, and the egg is given a quick twirl in order to cause the yolk and the white to rotate. The rotation enables the candler to observe the internal condition of the egg fairly well. A skillful candler in an hour is able under satisfactory conditions to candle from 2½ to 3 cases, each containing 30 doz. eggs.

During recent years attempts have been made to construct automatic candling devices, but for the most part they have not proved successful in the complete grading of eggs but are of service in certain phases of candling and grading. The "electric-eye" candler is constructed upon the principle of determining by means of a selective adjustment of electric light the degree to which an egg intercepts or refracts light rays. A considerable amount of experimental work has been carried on in recent years with a view toward improving candling devices for candling eggs by hand. It is anticipated that improvements made will permit of more accurate determination of the internal condition of eggs.

The holding of egg shows and egg-grading schools for the purpose of stimulating interest among producers, egg candlers, and dealers in problems of egg quality has accomplished a great deal of good. Students, particularly, are benefited considerably by the training they receive in candling and grading eggs. At many of the egg shows competition is very keen, with the result that producers are encouraged to take much more interest in factors that affect the quality of eggs. Candling demonstrations given in local communities have proved to be of great value. The use of a score card in judging and grading eggs is extremely worth while, because by this means producers, candlers, and dealers may learn a

great deal concerning the relative importance of different factors that affect egg quality.

MARKET-EGG SCORE CARD
For One Dozen

Exterior quality:	
Size (total weight)	12
Uniformity of weight	12
Uniformity of color	12
Uniformity of shape	10
Shell texture	12
Condition	6
Interior quality	36
Total	100

Size (total weight of exhibit).—A perfect score is given to the dozen weighing between 24 and 27 oz. If the average weight is within 1 oz. either above 27 or below 24 oz., cut 6 points. If more than 1 oz. either above or below, cut 12 points.

Uniformity of Weight.—The individual weight of each egg shall be determined in ounces per dozen. The weight per egg of the largest number of eggs in the entry having the same weight shall be taken as a standard. All eggs varying from ½ to 1 oz. of this standard shall be cut ½ point. Eggs varying 1 oz. or more from this standard shall be cut 1 point. No cut is made for the first ½-oz. variation from the standard.

Uniformity of Color.—If white, all eggs should be chalk white and free from creamy or tinted coloring. If brown, all eggs should be uniformly the same shade. A cut of ¼ point per egg may be made according to the actual shade of each egg and how well it conforms to uniformity of shade with the other eggs in the dozen.

Uniformity of Shape.—Each egg to conform as nearly as possible in shape to the other eggs in the dozen. Extremes should be avoided. Cut ¼ point for each egg off in shape or ridged.

Shell Texture.—The shell should be strong and of uniform thickness. Cut ¼ point per egg for rough shell. Cut ¼ point for blind check, 1 point for leaker or smashed egg.

Condition.—The eggs should be clean. Cut ¼ point for each dirty or stained egg.

Interior Quality.—Perfect score, per egg, 3; cuts per egg: A, or Extra, ¾; B, or Standard, 1½; C, or Trade, 2¼. Blood spot or meat spot, cut ¼ point. Note: Extra, Standard, and Trade grades of eggs are described in a later section of this chapter.

FIG. 162.—Score card for judging eggs.

Normal Egg under Candle.—The candling of a normal, fresh white egg gives a typical picture and is used here to illustrate the appearance of the average good eggs under the candle. Upon careful examination two characteristics are immediately noticeable: the outlines of the small air space at the large end of the egg and the diffused shadow of the yolk near the center of the egg.

The outstanding difference between thick and thin white is that the thin contains practically no mucin, whereas the thick is rich in this protein

substance, first demonstrated at the National Agricultural Research Center. The California Experiment Station has shown that there is no difference in the per cent of solids in the thick and thin portions of egg white. The same institution has also shown that the transmission of light through the egg varies with the percentage of mucin contained in the thick white.

If the structure of the shell is abnormal, it is very noticeable, of course, particularly if it exhibits spiral lines due to slight variations in the density and pigmentation of the shell, or light and dark spots due to moisture changes or to an uneven deposition of calcium and pigment in the shell.

The yolk of a normal fresh egg under the candle appears as a very dim shadow which whirls with the white of the egg as it is twirled in the hand. The yolk shadow gives the yolk the appearance of being suspended in the center of the albumen, and as the shadow whirls there is a gradual shading of the yolk color into the normal tone of the albumen. Accompanying the whirling yolk shadow is usually seen an indistinct dark spot followed by a light spot, the dark spot being produced by the rotation of the outer end of one of the chalazas, and the light spot resulting from the reflection of light from the inside of the shell shining through the chalazas.

Variations Detected by Candling.—Not only do fresh-laid eggs vary a great deal as far as their appearance under the candle is concerned, but eggs that have been held for some time and eggs that have been handled in different ways show many variations in shell and interior quality. The object in candling is to be able to detect the extent of these variations and thus grade eggs according to quality. Success in candling usually depends upon years of experience, the ability to determine the nature of variations in the internal condition of eggs, and knowledge of the physical properties of the egg contents that give rise to the variations observed under candling.

Air-cell Size.—In a normal fresh egg the air cell is about ⅛ in. in depth, but the longer an egg is held the larger the air cell becomes, depending upon the conditions under which the egg is held. For instance, a fresh egg held in a hot, dry room for one day may have a larger air cell than another egg held for weeks under proper storage conditions. The hotter and drier the atmosphere in which eggs are held the greater the evaporation of water from the egg and the larger the air cell.

Tremulous Air Cells.—Eggs that are handled very roughly or jarred severely may have the inner and outer shell membranes split apart beyond the edges of the normal air cell, giving rise to a condition known as "tremulous air cells." When eggs containing tremulous air cells are candled, the cells appear to move slightly as the eggs are twirled. The tremulous-air-cell condition apparently has no bearing on the quality

of the egg as human food but does affect hatchability, as shown by the results of tests conducted by the National Agricultural Research Center.

Yolk-shadow Changes.—It would naturally be expected that the darker the yolk in color the deeper would be the yolk shadow when the egg is twirled. Recent experiments have demonstrated, however, that the density of the yolk shadow is determined not only by the color of the yolk but by the proportions of thick and thin white and by their condition. As a matter of fact, yolk shadow may be a better criterion of egg-white condition than of yolk color. At Cornell University it has been shown that the yolk tends to become deeper in color as the air cell increases in size and as deterioriation progresses. Work at the California Experiment Station proves that shaking the egg tends to deepen the yolk shadow.

Blood Rings.—An egg with a blood ring appearing on the yolk is the result of the development of the embryo for a few days, after which it dies, leaving the blood of the embryo collected in a small ring. Producers should realize that the germ of a fertile egg starts to develop at about 68°F. One way of largely avoiding the occurrence of eggs with blood rings is to keep the males away from the females except during the breeding season.

Blood Clots.—Eggs with blood clots in them sometimes are observed among fresh eggs. The clot usually appears on the side of the yolk when the egg is candled. It is caused by a rupture of a blood vessel in the ovary, the blood collecting on the side of the yolk. Eggs with blood clots should not be marketed.

Blood Spots.—Very small spots of blood about the size of a pinhead in an egg are called "blood spots." Eggs with blood spots have no place in a high class egg market.

Bloody Eggs.—Bloody eggs are those in which the blood from a ruptured blood vessel in the ovary or oviduct mixes with the white of the egg, giving it a bloody appearance. Bloody eggs are very objectionable from a marketing standpoint.

Meat Spots.—Eggs with "meat spots" are those in which blood, from a rupture of the oviduct or during ovulation, becomes included with the white while the egg passes down the oviduct. Although eggs with meat spots are quite edible after the meat spots are removed when the eggs are broken, it is not advisable to market them. When eggs are candled, meat spots are often mistaken for blood clots or for one of the chalazas, but experience in candling will show the blood clot located near the yolk, and the meat spot is not accompanied by the refracted light spot of the chalazas.

Heat Spots.—A heat spot appears as a reddened spot on the surface of the yolk of a fertile egg and is due to early embryo development which is later arrested.

"Grass" Eggs.—Grass eggs are those in which the yolk appears brownish or dark slate in color and the white has a greenish cast. The Washington Experiment Station has shown that diet is not responsible for the production of grass eggs, in spite of the opinion of many to the contrary. Some believe that grass eggs are produced more frequently in the spring of the year than at other times. It is possible that the condition may be due to the influence of bacteria.

Pinkish Whites.—The Texas, California, Michigan, and Oklahoma experiment stations have shown that a condition known as "pinkish white" may result from feeding the laying hens such feeds as cheese weed, crude kapok oil, and crude cottonseed oil. Although this condition is sometimes detectable upon candling, it disappears when the eggs are cooked, but the white is frequently tough and rubbery.

Mottled Yolks.—In the chapter on Feeding Practice it was shown that certain feeds produce a discoloration of the yolk, giving it a mottled appearance. Work at the Michigan Experiment Station has demonstrated that the mottled appearance of the yolk is sometimes due to the imperfect condition of the peripheral layer of light yolk, allowing areas of dark yolk lying beneath to show through.

Loose Shell Membranes.—Very occasionally fragments of the inner and outer shell membranes, apparently secreted at a time when no egg is being formed in the oviduct, become included in the white of an egg. Such defects are called by candlers "tapeworms."

Blind Check.—An egg with a crack in the shell so small that it can be detected only by candling or by tapping the egg against one sound in shell is known as a "blind check."

Body Check.—An egg termed a "body check" is one in which the shell has apparently been cracked in the uterus of the oviduct and then more shell material is deposited over the crack.

Leakers.—Leakers are cracked eggs from which the contents are leaking.

Light and Heavy Floats.—The excessive heating of eggs, whether from extreme exposure to the rays of the sun or by being held in warm places, gives rise to two different kinds of eggs known as "light floats," and "heavy floats." Light floats as they appear before the candle have enlarged air cells and darkened yolks. The eggs have a darkened and heated appearance and deteriorate more readily than fresh eggs. Heavy floats are more seriously defective than light floats because the air cells are larger and the yolks are much darker and closer to the shell.

Moldy and Musty Eggs.—Moldy and musty eggs are the result of molds on the outside or inside of the shell, especially if the shell is cracked.

Rots.—Rots of various kinds are the result of bacterial infection, although normal fresh eggs are practically sterile. Moldy eggs and those

with rots contain a relatively high percentage of bacterial infection. Many kinds of eggs with rots are found in commercial practice.

The first stage of bacterial decomposition gives rise to a condition known as "addled," "sour," or "white rot." Upon candling such an egg it usually appears to be very watery, but close inspection reveals light and dark streaks crossing the line of vision.

CAUSES OF DETERIORATION IN QUALITY

Among all foods used by human beings eggs are unique because their contents are enclosed in a naturally prepared shell package which serves as a protection against deterioration; but since the contents are highly perishable, the shell serves to conceal from the prospective consumer the deterioration that may have taken place. The shell is therefore both an asset and a liability.

The contents of a normal fresh egg represent one of the best foods in the human diet, but deterioration progresses rapidly when eggs are subjected to improper conditions of handling and storage. Proper steps in order to retain the original high quality of fresh-laid eggs can be taken only when an understanding is gained of the numerous factors that cause deterioration.

High Temperature Ages Eggs.—Some of the most noticeable changes that take place in eggs are due to high temperatures in which they are frequently held. Water evaporates through the porous shell, the air cell enlarges, the thick white breaks down, the thin white becomes quite watery, the vitelline membrane surrounding the yolk becomes weaker, and the yolk becomes more flaccid. Such is a gross picture of what takes place in the aging of eggs, a process that is governed largely by the conditions under which eggs are held, irrespective of time. Other changes also take place, including those of odor and flavor, depending upon the environment in which eggs are kept. An egg of superior quality kept in a bad environment ages much more quickly than one of fair quality kept in a good environment. Most poultry producers and egg dealers fail to appreciate the fact that the yolk and white of an egg are very sensitive to unfavorable conditions of holding and handling.

Since the embryo starts to develop in a fertile egg if it is kept in a temperature above 68°F., it is obvious that eggs should be held below that temperature, the most practicable range being between 40 and 63°F., a temperature of about 55°F. being considered the optimum.

Alternately high and low temperatures, such as occur from daytime to nighttime in many sections of the country during the summer months, give rise to a condition recognized as "heat spots." Embryo development begins and then is arrested, a reddened spot appearing on the surface of the yolk when the egg is candled. Unless such an egg is kept in a cool

temperature it is very liable to develop into a "rot." In infertile eggs the alternately high and low temperatures of summer apparently cause the yolk to assume a mottled appearance, the aging of the egg proceeding rather rapidly if it is not placed in a cool temperature immediately. Infertile eggs do not spoil nearly so rapidly as do fertile eggs under ordinary methods of handling and storing.

In addition to the aging of eggs in high temperatures, the evaporation of the water content of the egg causes a loss in weight that is of great

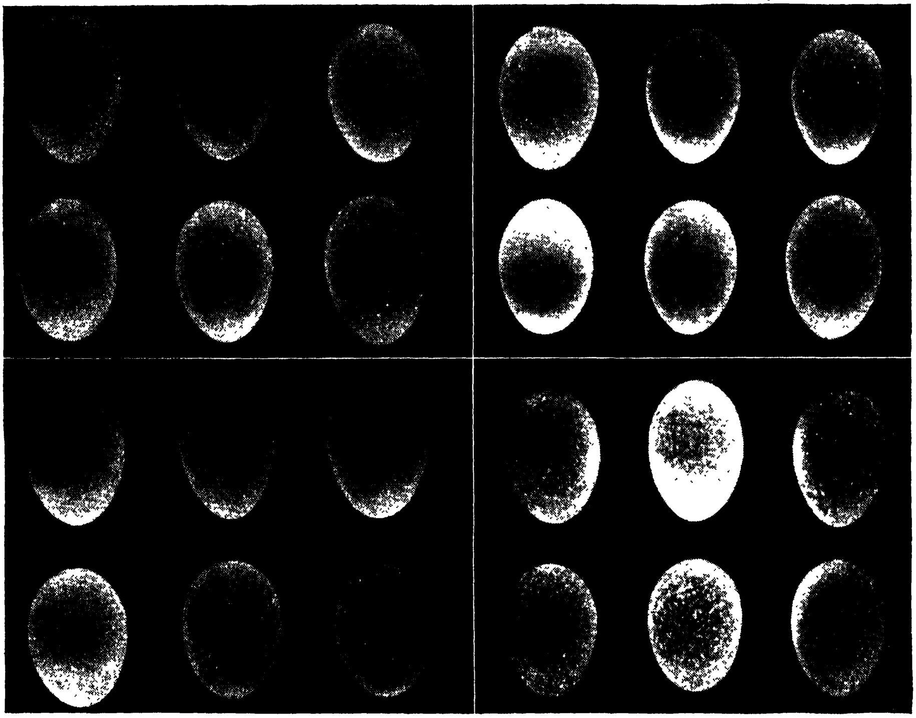

FIG. 163.—Showing mottling in the shell due to low humidity. At the top left are 6 eggs photographed about 2 hours after being laid, and at the top right are the same eggs photographed after being held for 12 days in a room having an average daily temperature of 65°F. and a relative humidity of about 92 per cent. At the bottom left are 6 eggs photographed about 2 hours after being laid, and at the bottom right are the same eggs photographed after being held for 12 days in a room having a temperature of 65°F. and a relative humidity of 64 per cent. (*Univ. of Del.*)

practical importance in marketing. Standard market size is 2 oz. per egg, or 1½ lb. per dozen, or 45 lb. per 30-doz. case. A shrinkage of only 5 per cent would mean a loss of 2.25 lb. per 30 doz., which would then weigh only 42¾ lb.

Liquefaction Changes Quality.—It has already been observed that when eggs are held in too high a temperature there is a general breaking down of the white of the egg, a weakening of the vitelline membrane, and increased flaccidity of the yolk. As eggs age the white decreases in

viscosity so that the yolk floats nearer to the shell, casting a darker shadow. This liquefaction appears to be due in part to the influence of osmotic pressure as the result of which water passes from the white of the egg to the yolk. The contents of the yolk become more fluid, and the vitelline membrane is stretched so that when such an egg is broken open the yolk tends to flatten out.

The results secured from work done at Cornell University and the California Experiment Station indicate that liquefaction tends to be reduced by preventing the loss of carbon dioxide from the egg either by placing the eggs in an atmosphere of carbon dioxide or by sealing the pores of the shells with oil. It should be noted that under normal holding conditions eggs lose carbon dioxide, rapidly at first and then more and more slowly. Workers at the California Experiment Station have suggested that liquefaction is due to two different processes: (1) In low concentrations of carbon dioxide the long mucin fibers of the thick white break up into shorter fibers; and (2) in excess concentrations of carbon dioxide the long mucin fibers of the thick white contract and squeeze a liquid solution of other proteins from the thick white.

The possible cause of the liquefaction of the thick white has been studied from another angle by research workers in the Bureau of Chemistry and Soils of the U. S. Department of Agriculture. It was observed that thin white is formed from thick white by the action of a tryptic proteinase contained in the thick white and that the thin white contains an antitrypsin which inhibits the action of the enzyme after thin white has been formed. It was also found that the injection of trypsin into the thick white hastened liquefaction. At the Kansas Experiment Station it was discovered that the inner layer of thin white, immediately surrounding the yolk, contains by far the most of the inhibiting substance responsible for the resistance of the thick white of fresh-laid eggs to proteolytic activity.

Chemical Evidence of Quality.—Certain chemical changes take place in eggs, their extent depending in some measure upon the conditions under which eggs are held. In the yolk there is a progressive increase in the water content, the acid number of the fat, inorganic phosphorus, and loosely bound ammonia. In the white there is apparently no decrease in glucose and no definite increase in the simpler protein fractions in the uninfected egg until it reaches the inedible grade.

Hydrogen-ion Concentration and Quality.—The hydrogen-ion concentration of fresh egg white and fresh egg yolk, expressed as pH, has been variously reported as from 7.5 to 8.2 for egg white and from 6.0 to 6.3 for the yolk. Since carbon dioxide escapes from the egg, as pointed out previously, the acidity decreases, and the alkalinity increases the longer the eggs are held, at least up to a certain point. In eggs that have

been held for some time the pH value of the white has been variously reported as from 8.9 to 9.5, and the pH value of the yolk as from 6.5 to 6.9. It should be observed that a relatively small increase in the pH value of egg contents indicates a marked change in alkalinity and that the change takes place much less rapidly at low than at high temperatures. The pH of the white of the egg is one of the controllable factors in the storage of eggs, practical use being made of the factor by adding carbon dioxide to the atmosphere of storage rooms in which eggs are being stored.

Molds and Bacteria Lower Quality.—The development of molds and bacterial infection are two very important factors causing the spoilage of many eggs. Washing dirty eggs sometimes gives rise to bacterial contamination on the inside of the shell. Molds develop, for the most part, in the presence of moisture on the shell of the egg, which may be the result of the eggs' "sweating" or some of the egg contents' seeping through a cracked shell. Moldy eggs frequently possess a pungent odor and musty flavor.

Although the contents of fresh eggs are practically free of bacteria, the presence of moisture and dirt on the shells is favorable to bacterial infection. That such does occur is evidenced by the appearance of rots of various kinds. Recently workers in the Department of Agriculture of South Australia have reported the finding of an organism, cultured from the ground chalazas of infected eggs, responsible for the development of the excessive mobility of the yolk and in many cases an increased yolk shadow upon candling.

Odors and Flavors Absorbed.—The porous nature of the eggshell allows the egg to absorb odors and flavors quite readily, so that eggs should not be allowed to come in contact with such foods or materials as onions and kerosene. Musty flats, fillers, and cartons should never be used.

PRESERVING EGG QUALITY

The importance of preserving the superior quality of fresh-laid eggs cannot be overemphasized, because the quality of market eggs affects their price, the number consumed, and the costs of marketing. The marketing of bad eggs means loss in shipping costs and a lower average price for all eggs marketed. The greater the care given in preserving the quality of eggs on the farm the less the expense involved in relation to their value in maintaining their quality while they are passing through the various channels of distribution and the greater the consumption. Stale eggs kill the demand for eggs more than high prices do. In all probability any appreciable increase in the per capita consumption of eggs will depend upon the extent to which the average quality of all eggs marketed is improved.

From what has been said previously in the section on causes of deterioration in egg quality, it is apparent that a reasonably low temperature is the first requisite in the preservation of egg quality. Other factors of outstanding importance include the humidity of the atmosphere in which eggs are held, the cleanliness of egg shells and all utensils and equipment used in handling and packing eggs, conditions of handling and storing, and the time that elapses between the production and consumption of the eggs.

Farm Preservation of Quality.—The few necessary details in the preservation of the high quality of fresh-laid eggs constitute some of the most profitable items of investment in the business of egg production. Clean litter in the poultry house, plenty of clean nests, screened droppings

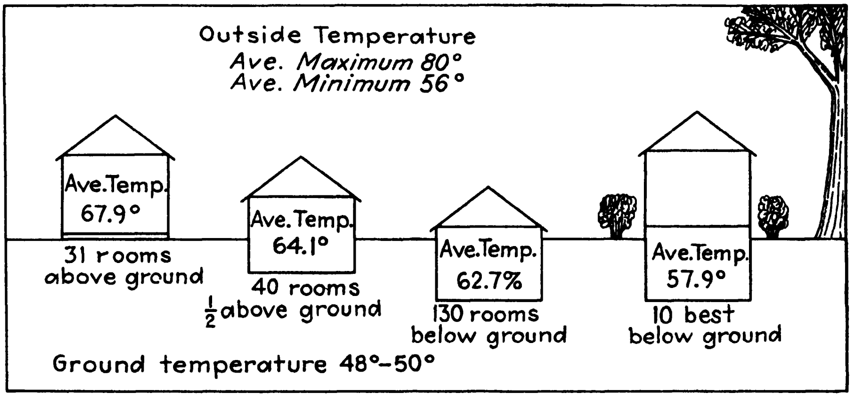

FIG. 164.—Showing temperature differences in Connecticut egg-cooling rooms. (*Jones*, 1933.)

boards or pit, the frequent gathering of eggs in wire baskets, and prompt cooling in a sanitary and well-ventilated egg room are some of the more important essentials that ensure the preservation of superior egg quality.

Apparently the greatest need on the majority of farms and commercial poultry plants for the preservation of egg quality is a suitable egg-cooling room where a temperature of about 55°F. can be maintained. The extension service of the Connecticut Agricultural College found that among 201 egg rooms on poultry plants the average temperature taken the first week of each month during June, July, and August in 1932 averaged 63.6°F. The average temperature for the three different kinds of egg rooms was as follows: 31 rooms entirely aboveground, 67.9°F.; 40 rooms one-half below ground, 64.1°F.; 130 rooms below ground level, 62.7°F. Among the 130 rooms below ground level were 10 that had a building above the egg room, and in these 10 egg rooms the temperature was 57.9°F.

In constructing an egg room some of the important points to be kept in mind include the following: (1) The walls should be thick and well

banked with earth; (2) the outside entrance should be preferably on the north side, and there should be a vestibule; (3) the ceiling and any partitions in the room should be well insulated; (4) relatively small windows or openings should be provided for ventilation; (5) the atmosphere should have a relative humidity of 70 per cent or higher, and this can be accomplished by occasionally throwing water on the floor or allowing water to evaporate from burlap hung on the wall and kept moist by a drip system. If mildew tends to develop on the burlap, the latter may be dipped in a dilute solution of copper sulfate, 1/8 lb. per gallon of water. If the eggs have a tendency to "sweat" when removed from the egg room to be marketed, the difficulty can be overcome to a large extent by removing them at night or early in the morning.

The Missouri Experiment Station conducted a number of interesting observations on the cooling of eggs on the farm, the results being of great practical importance to egg producers everywhere. With a few changes, the conclusions drawn from the investigations and the practical suggestions offered for the preservation of egg quality are given here.

1. Eggs should be gathered frequently each day during hot weather and placed in containers where they are exposed directly to cool air.

2. They should be gathered in a wire basket and held overnight in a cool place in the basket or on wire trays to permit all heat to escape from them. When cooled, they should be cased and held in a cool place until taken to market.

3. Eggs ranging in temperature from 92 to 102°F. when held in an egg room of 50°F. temperature required the following lengths of time, respectively, to be cooled to below 68°F.: single egg, 1 hr.; an egg in the center of three layers of eggs on a wire tray, 3 hr.; an egg in the center of a wire basket, 5 hr.; an egg in the center of a galvanized pail, 10 hr.; an egg in the center of a chilled case, 15.5 hr.

4. Eggs held in a household refrigerator in containers similar to those used in cooling eggs in an egg room (50°F.) cooled more rapidly than when they were cooled in the egg room, because the difference in temperature between the egg and the surrounding air was greater.

5. The circulation of air in the refrigerator or egg room increased the rate of cooling, particularly when the eggs were held on a wire tray or in a wire basket. In an egg room the circulation of air could be obtained by the use of an electric fan.

6. Eggs placed in cases that had been chilled cooled more rapidly than those placed in warm cases.

7. The problem of preventing an increase in temperature is as important as that of cooling eggs. The use of chilled cases, case liners, and insulation for the cases reduces the rate at which the temperature of

the eggs increase when they are exposed in their containers to high temperatures.

8. Eggs should not be placed in cases until the temperature of the eggs has been reduced. The use of cool cases instead of warm ones will help keep eggs cool. The flats, fillers, and cases carry considerable heat which should be removed by cooling them before the eggs are cased.

9. Circulating air in the egg room speeds up cooling very greatly, especially if the eggs are held in a wire basket or on a wire tray. If the air is dry, its circulation will increase evaporation so that the benefits from rapid cooling may be lost by the damage resulting from the increased

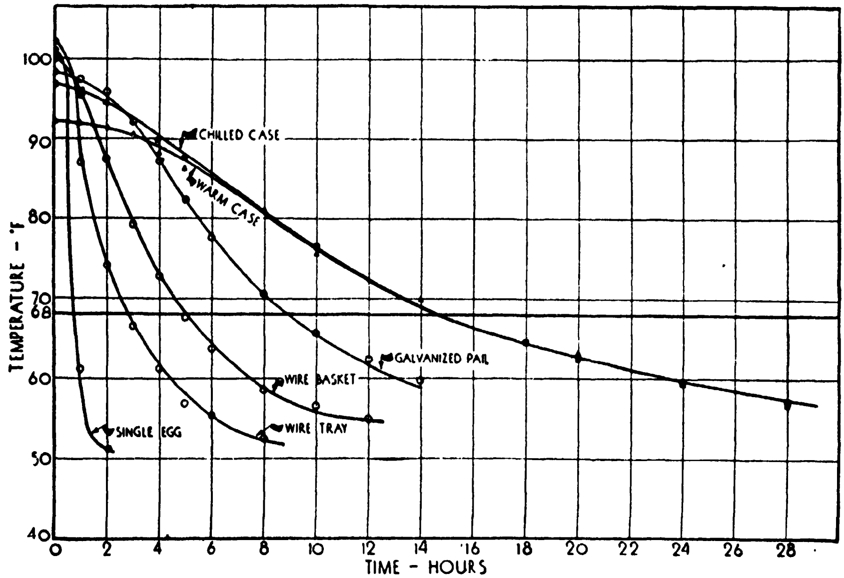

FIG. 165.—Graphs showing the time required for the interior of an egg to cool from approximately 100°F. to below 68°F., when held in the different containers indicated. (*Funk*, 1935).

size of the air cell. Where facilities are available for increasing air circulation the practice would be advisable, particularly if a relatively high humidity can be maintained.

10. The room or cooler used should have a relatively high humidity, which may be maintained by keeping the floor damp and by hanging pieces of wet burlap in the room. Evaporation of moisture from the floor or the burlap will tend to reduce the temperature of the room or cooler.

11. The use of case liners or other insulation tends to keep eggs cool when their containers are exposed to high temperatures. When eggs are cooled on the farm or in the dealer's plant and later exposed to high temperatures in transit, they should be protected by shade and insulation.

The producer will find that wrapping a case in a piece of canvas or blanket to prevent the sun from shining on the case will help to keep eggs cool while they are being taken to market.

Another necessary step in preserving egg quality is frequent marketing, especially in warm weather. Other things being equal, the more frequently eggs are marketed the better the price usually received and the greater the profits in production. Their proper protection while being marketed is most essential in the preservation of quality and in commanding top prices.

Washing Dirty Eggs.—On most farms a certain number of dirty eggs are inevitable, and since they should not be marketed in that condition

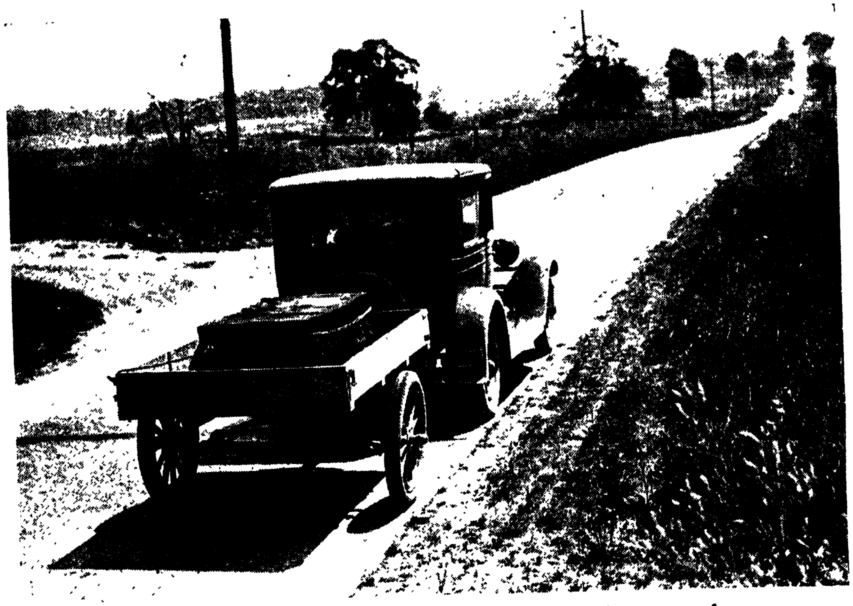

FIG. 166.—A farmer delivering eggs to market. Note that the cases of eggs are covered with a damp blanket to protect the eggs from the hot sun. (*Menefee.*)

they present a problem, because washing them with water has been found to result in rapid deterioration in quality, especially if they are stored. Experimental work conducted by the Missouri Experiment Station has shown, however, that dirty eggs washed with water containing 0.5 or 1 per cent sodium hydroxide were practically equal in interior quality to clean unwashed eggs after 8 and 10 months of storage. Sodium hydroxide dissolved in water, otherwise known as "lye water," is an odorless substance which is effective in destroying microorganisms in the dirt on the shell but does not affect the appearance of the shell or the flavor of the egg.

Cooking tests demonstrated that dirty eggs washed with lye water were comparable in quality with clean unwashed eggs. Since it is a common practice to break open eggs with dirty shells in order to freeze

them, it is interesting to note that by washing the dirty shells with a 1 per cent solution of lye water the bacterial content of the frozen whole-egg product was considerably reduced as compared with the frozen whole-egg product obtained from eggs with dirty shells that had not been washed, the bacterial counts having been made after 9 months of storage.

In the washing process rubber gloves should be used, and the lye water should be changed sufficiently often to make sure of its effectiveness in destroying contamination.

FIG. 167.—Cool, circulating, and humidified air, as well as cleanliness is necessary for the preservation of egg quality. (*Eastern Division, Armour & Co.*)

Preserving Quality in Storage.—Producers in all parts of the country should appreciate the function that the cold storage of eggs serves in regulating prices in such a way as to increase production returns. Over one-half of the total annual egg crop in the United States is produced in the 4 months of March, April, May, and June. This uneven seasonal production results in a surplus of eggs during the spring and early summer seasons and a corresponding scarcity during the fall and winter months. On the other hand, the consumption of eggs is fairly stable throughout the year except that in the spring months it is greater but is still not enough to take up the surplus produced during that time.

Although for many years it has been customary to hold eggs in storage for approximately 7 or 8 months, the tendency is for the storage period to be shortened to about 4 or 5 months. This change is largely the result of relatively heavier egg production during January and February in

recent years as compared with several years ago. Many cold-storage operators have found it highly advantageous to dispose of their storage holdings during the late summer and early fall months.

The surplus eggs are packed in 30-doz. egg cases, with new fillers and flats, placed in cold storage, and then taken out again to make up the shortage in egg supply during the fall and winter months. The placing of eggs in cold storage and holding them there to put on the markets when there is a shortage tends to stabilize prices. At the same time it is estimated that approximately only about 10 to 15 per cent of the total annual production of eggs is placed in storage each year. The proper storage of these eggs with a view toward preserving their quality is of great importance, because their quality when taken out of storage influences the general price level of all other eggs.

Since it has been shown that for different lots of eggs kept under similar conditions of storage the quality of the eggs upon being taken out of storage is in direct relation to their quality when placed in storage, it is obvious that the greatest possible care should be exercised in the selection of only the best possible quality of eggs for storage purposes.

Much research has been undertaken to determine the proper conditions of temperature, humidity, and ventilation necessary for preserving egg quality. The temperature of storage rooms should be held at 29 to about 30°F., but each storage room must be tested separately to determine the proper humidity and ventilation to be maintained.

A high relative humidity in the storage room is desirable in order to prevent excessive evaporation of water from the eggs, but mold grows luxuriantly if the relative humidity at the shell surface is 96 per cent or higher. At relative humidities ranging from 90 to 94 per cent a slight white mold called "whiskers" occurs, many storage operators using this phenomenon as an indication that a desirable relative humidity is being maintained.

Except at extremely low velocities, the rate of evaporation of water from the egg is independent of air circulation. However, an imperceptible movement of air in the storage room eliminates the gradient in the atmosphere so that the humidity at the shell surface is the same as elsewhere in the storage room. The forced circulation of air maintained in many storage rooms permits a higher relative humidity to be maintained in the aisles between the rows of stored cases of eggs. An increase in relative humidity reduces evaporation of water from the eggs in the more exposed portions of the cases but has relatively little effect on those in the center. When the relative humidity is kept approximately constant, an increase in air circulation has little effect on the rate of evaporation of water from the eggs in the outer layers of the cases but does tend to increase it in the interior.

Ozone is used in many cases for the purpose of checking odors and mold growth. Carbon dioxide has also been introduced into storage rooms for the purpose of preserving egg quality, as observed previously.

When eggs are taken out of the cold-storage room they should be held for awhile in another room in which the temperature is not more than about 15°F. higher than that of the cold-storage room. In other words, whenever eggs are moved from a "holding" room to another room, the change in temperature should not exceed about 15°F.

Oil-treated Eggs.—It has been pointed out previously that the highest quality in eggs is found in fresh ones when they are produced under sanitary and otherwise satisfactory conditions. A method of treating fresh eggs to preserve the quality has been developed in recent years. The eggs are dipped for a few seconds in a solution of odorless, tasteless mineral oil heated to a temperature of 225 to 240°F., although recently a much lower temperature has been used with good results. The coating of the eggs with the oil seals the pores of the cells. This prevents the evaporation of the water content from the egg and tends to preserve its original quality.

The bulk of the oil-treated eggs are placed in cold storage, and when they are removed they are sold in the oil-treated condition, or sometimes the oil is removed from the shells by passing the eggs through a sandblast. This is sometimes referred to as "manicuring" the oil-treated eggs, and when so treated they must be sold soon thereafter, because the pores of the shells have been opened, permitting relatively rapid evaporation to take place. Recently some experimental work has been undertaken with a vacuum-carbon dioxide method of oil treating eggs, the results indicating that interior quality is maintained somewhat better under conditions of storage than in eggs oil treated by the ordinary method.

Home Preservation of Eggs.—The home preservation of eggs has been practiced for many years. When prices are low in the spring it is frequently advantageous to preserve a few eggs for cooking and baking purposes during the fall and winter months. Only fresh eggs of the very best possible quality should be used, and they should be clean and sound in shell.

The eggs are preserved in a solution of water glass (soluble sodium silicate). To 9 parts boiled rain water that has been cooled add 1 part water glass. Put the solution in an open crock, and place the eggs in it as they are gathered every day. Place them with the large end uppermost, and be sure that there is at least 2 in. of the solution above the top layer of eggs. The eggs may be kept in the solution for several months. If they are to be cooked, pierce the air cell with a needle to prevent them from cracking during the process.

Freezing Eggs.—The freezing of the yolks and whites of eggs is a method of preserving egg quality that has proved to be of outstanding importance to the industry. The frozen-egg industry has been of service in two ways: removing surpluses during the spring flush season and providing the bakeries with a product that is more conveniently used in baking than eggs in the shell.

It has been pointed out previously that over one-half of the annual production of eggs is produced in the 4 months of March, April, May, and June. Many of these eggs are frozen and stored for future use. The industry has developed to considerable proportions, the freezing season

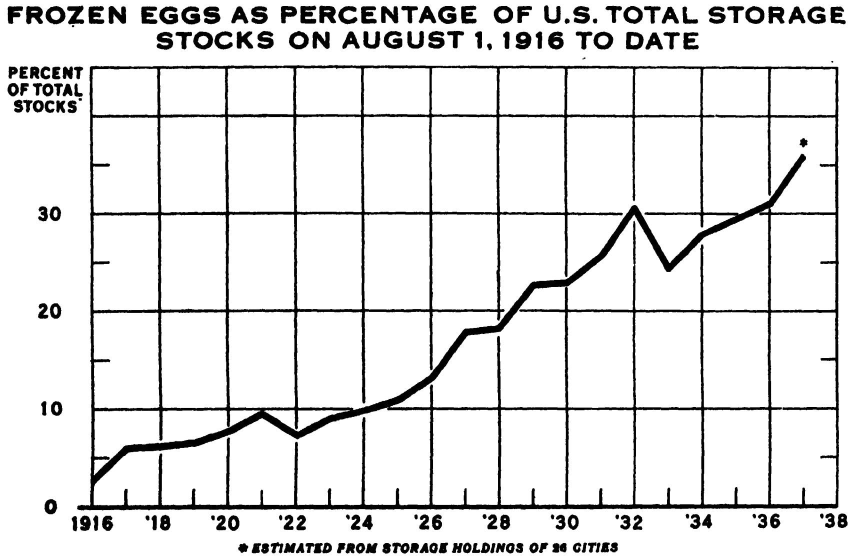

FIG. 168.—The egg freezing industry has expanded considerably during recent years. (*U. S. Dept. Agr.*)

each year often extending up to September. Most of the eggs for freezing are obtained from the central and southwestern parts of the country.

The baking, candy-manufacturing, and mayonnaise-manufacturing industries as well as others have benefited from the expansion and development of the frozen-egg industry. The product is available in convenient form for many purposes, although once it is removed from storage it should be used rather quickly. The white or albumen portion of the egg, which is used in cakes, candies, and meringues, is not appreciably altered by freezing. On the other hand, the freezing of the yolks, which are used in noodle and mayonnaise manufacture, precipitates the lecithoprotein, the substance responsible for the emulsifying properties of the yolk. When substances such as salt, sugars, or glycerin are added to yolks that are to be frozen, the freezing point can be lowered, and the frozen yolks can be stored at much lower temperatures. Precipitation

occurs when the yolks with these substances added are actually frozen. The freezing of whole eggs, which are used principally by bakers, may alter their physical properties.

Eggs that are to have their contents frozen are chilled at about 40°F., then candled in a chilled room. The good eggs are sent directly to the breaking room, which is kept at about 60°F., and here they are broken open by trained girls who use sanitary methods in all operations in the handling of the eggs. All utensils are sterilized frequently, and care is taken to keep the breaking room clean. The eggs are examined by the eye and are smelled for odors, a keen sense of smell being very important.

FIG. 169.—A mechanical apparatus for breaking eggs and for separating yolks and whites for the preparation of frozen and dried egg products. (*Poultry Craftsman and Breeder.*)

The broken egg is separated into the white and the yolk parts, the yolk being dropped into a cup. Both the white and the yolk are then dropped into the can in which they are to be frozen.

The whites and yolks, each in considerable bulk, are passed over baffle plates or other apparatus for the purpose of removing bits of shell. Before the yolk mass is frozen, the vitelline membranes must be crushed, and then salt, 5 per cent of glycerin, or 10 per cent of sucrose are added before churning, which precedes freezing. Sometimes whites are not churned before being frozen, although churning hastens beating quality. Sometimes yolks and whites are mixed for freezing, churning being necessary before the mixture is frozen. In many cases emulsifying agents are added to the white or the white-and-yolk mixture before freezing.

Whether frozen yolks, frozen white, or frozen whole egg is being prepared, the contents in each case are poured into cans which hold approximately 30 lb. of frozen product. The cans are then placed in a sharp freezer where a subzero temperature is maintained and the contents are frozen solid, after which the cans may be held in a room with a temperature of 0 to 5°F. until sold. The frozen contents are not thawed out until they are to be used.

A 30-doz. case of eggs, weighing approximately 45 lb., yields about 34 to 36 lb. of whole-egg mixture or about 15 lb. of egg yolk and 20 lb. of white.

FIG. 170.—The interior of an egg-breaking plant. The manufacture of frozen and dried eggs requires strict sanitation in the various operations. (*Poultry Craftsman and Breeder.*)

Drying Eggs.—The drying of eggs is another method of preserving egg quality which has developed into considerable proportions in this country in recent years. Most of the eggs used for drying are produced in the southwestern sections of the country, surplus supplies during the spring and early summer being used for the most part.

The dried-egg industry serves to remove surpluses which accumulate in seasons of heavy production and provides the baking and confectionery industries with an extremely useful product well adapted for a variety of purposes.

Three of the most commonly used methods of drying eggs include the belt, the spray, and the pan.

In the belt method the whole-egg mixture is placed in layers on a 4-ft. continuous aluminum belt which passes through a 160°F. room about 100 ft. long, the flaked product being scraped off the belt after sufficient

drying. The dried-egg product must be in storage at a temperature between 40 and 50°F.

In the spray method, whether dried yolk, dried white, or dried whole-egg mixture is being prepared, the product is sprayed under 1,500 to 3,000 lb. pressure through nozzles into a chamber kept at about 150°F. The moisture being removed, the dried product falls to the floor as a powder, which can be kept in dry storage for approximately one year without refrigeration. There has recently been developed in the United States an improved new drying process, most of the experimental work apparently having been devoted to the manufacture of dried white. The liquid egg whites are pumped under pressure and are atomized by a nozzle, the spray encountering a blast of warm air in a conical-shaped chamber at the bottom of which there is a suction machine which draws the powder through into a hopper where it is barreled. This dried egg white is sold to the bakery trade as a mixed meringue powder, all ingredients having been added except sugar, water, and flavoring.

TABLE 53.—APPROXIMATE CONVERSION EQUIVALENTS FOR EGGS AND EGG PRODUCTS[1]
(U. S. Department of Agriculture)

1 Lb. of	Is Equivalent To
Frozen or liquid egg..	10.2 U. S. eggs in shell
Dried whole egg.....	3.6 lb. liquid whole egg[2]
Dried yolk..........	2.25 lb. liquid yolk[2]
Dried albumen......	7.3 lb. liquid albumen[2]
Liquid whole egg....	0.55 lb. liquid white plus 0.45 lb. liquid yolk[3]
Dried whole egg.....	0.25 lb. dried white plus 0.75 lb. dried yolk[3]

[1] In commercial separation of white and yolk a part of the white adheres to the shell and also to the yolk, hence is not a perfect separation. Owing to variation in such factors as egg weights and the like, the data given should not be used as a basis for calculating formulas for the production of manufactured egg-food products to conform with the minimum requirements of existing legal standards for such products.

[2] Tariff Information Surveys, G.11—Eggs and egg products, U. S. Tariff Commission.

[3] Industry sources.

In the pan-drying method the egg white is poured through a sieve into wooden casks where fermentation is allowed to take place, after which the liquid product is dried on trays in a room in which the temperature may vary from time to time considerably above or below 120°F., the length of the drying period depending somewhat upon the temperatures maintained. It is then removed and placed on tables to cure for 24 hr., after which it is ready to be packed for marketing.

Officials of the U. S. Department of Agriculture have shown that the scum that normally occurs in the drying process may be recovered for drying by the addition of citric acid and an acid solution of the enzyme pepsin.

It has been determined that 30 doz. eggs of normal size produce on the average 9 to 10 lb. of dried whole egg, or 7 to 7.5 lb. of dried yolk and 2 to 2.5 lb. of dried white.

GRADING EGGS IN THE SHELL

It has been shown previously that all eggs as they are sold by producers are not of the same quality, but even if they were they would show differences before they reached the consumer. Differences in methods of handling eggs and different lengths of time for various lots of eggs to reach the various markets produce changes in their quality. In order to provide a practical basis for reporting prices and for buying and selling according to quality, the various markets have established certain grade standards based on quality. The particular grade into which a particular lot of eggs is classified depends in a large measure upon the extent to which their original quality has been preserved.

The establishment of grades of eggs is based upon differences that exist with respect to their exterior and interior quality. The different characteristics determining exterior quality that are taken into consideration in grading eggs include: cleanliness of shell, soundness of shell, size, color, and shape. The different characteristics determining interior quality that are taken into consideration in grading eggs include: the condition of the yolk, the condition of the white, and the size and condition of the air cell. By far the most important of these various characteristics that determine grade are the condition of the yolk and the condition of the white, although cleanliness of shell is of paramount importance in enabling eggs to qualify for any of the better grades.

In actual practice there are many different grades of eggs, including those established by wholesalers, jobbers, and retailers; but lack of space precludes their discussion in this book, which is designed primarily for producers. From time to time efforts have been made to adopt uniform standards of grading that would apply to all eggs marketed in various sections of the country. The Bureau of Agricultural Economics of the U. S. Department of Agriculture has established standards for individual qualities of eggs that might well serve in the adoption of any grading system. As a matter of fact, many state grades have been adopted based on the federal standards. These standards for individual eggs are also used in setting up wholesale grades, in each of which there must be a certain minimum percentage of eggs that possess the individual qualities characteristic of the particular grade. The standards for individual qualities will undoubtedly continue to serve as the basis for most of the grading regulations that may be adopted from time to time and are believed to constitute a suitable basis for the development of a national program of egg standardization.

U. S. Standards for Eggs with Clean, Sound Shells.—Standards are provided for four qualities of clean, sound-shell, edible eggs, *viz.*, U. S. Special, U. S. Extra, U. S. Standard, and U. S. Trade.

Specifications for U. S. Special.

The shell must be clean, sound, and normal.

The air cell must not exceed 1/8 in. in depth and must be regular.

The yolk must be well centered, its outline indistinct, and it must be free from visible germ development and other defects or blemishes.

The white must be firm and clear.

Specifications for U. S. Extra.

The shell must be clean, sound, and normal.

The air cell must not exceed 2/8 in. in depth and must be regular except in the retail grade of U. S. Extra, when it may be slightly tremulous.

The yolk must be fairly well centered, and its outline may be moderately defined. It may be slightly mobile but must be free from visible germ development and practically free from other defects or blemishes.

The white must be firm and clear.

Specifications for U. S. Standard.

The shell must be clean and sound but may be slightly abnormal.

The air cell must not exceed 3/8 in. in depth and may show movement not in excess of 1/2 in.

The yolk outline may be well defined. The yolk may be mobile and may show slightly visible germ development and other definite but not serious defects.

The white must be reasonably firm and clear.

Specifications for U. S. Trade.

The shell must be clean and sound but may be abnormal.

The air cell may be over 3/8 in. in depth, may show movement in excess of 1/2 in., and may be bubbly or free.

The yolk may be plainly visible. It may be freely mobile and cast a dark shadow. It may show clearly visible germ development but no blood. It may show other serious defects.

The white may be weak and watery.

Standards for Eggs with Dirty Sound Shells.—Standards are provided for three qualities of dirty sound-shell eggs, *viz.*, U. S. Extra Dirty, U. S. Standard Dirty, and U. S. Trade Dirty. The specifications for dirty-shell eggs of each of these three qualities are the same as for the corresponding quality of clean-shell eggs except that the shell may be only slightly stained or slightly dirty in the U. S. Extra Dirty, and it may be stained or dirty in the U. S. Standard Dirty and the U. S. Trade Dirty.

Standards for Eggs with Checked or Cracked Shells.—One standard is provided for eggs with checked or cracked shells, *viz.*, U. S. Check.

The specifications for eggs of this quality are the same as for clean sound-shell eggs of the quality of U. S. Trade or better except that the shell may be checked or cracked but not leaking, and it may be clean, stained, or dirty.

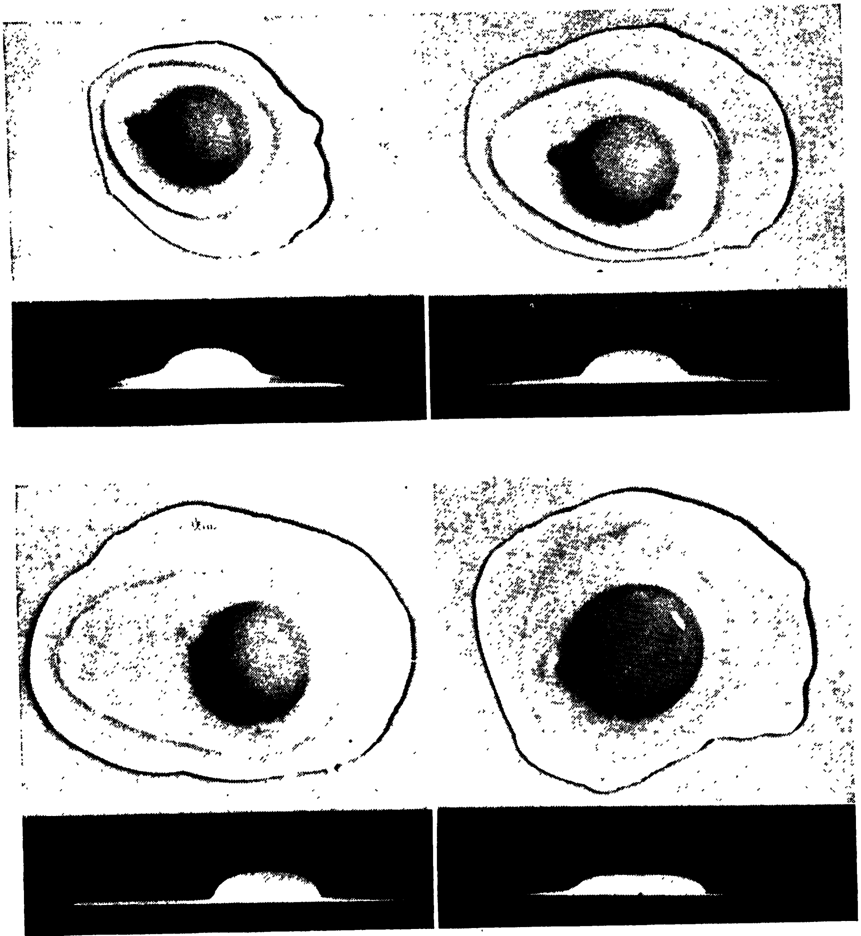

FIG. 171.—The "broken out" appearance of four grades of eggs. Upper left, equivalent to U. S. Specials; upper right, equivalent to U. S. Extras; Lower left, equivalent to U. S. Standards; Lower right, equivalent to U. S. Trades. Note the marked difference in the "standing-up" quality of the yolk and the white among the eggs of the different grades. (*Van Wagenen.*)

Terms Descriptive of Shell.—Certain terms are employed for the purpose of distinguishing the different kinds and conditions of shell that are usually encountered.

1. Clean. A clean shell is one that is free from foreign matter and from stains or discolorations. Eggs that show traces of processing oil on the shell are considered clean when classified as processed or shell-treated eggs unless the shell is otherwise soiled.

2. Sound. A sound shell is one that is free from checks, cracks, or blind checks.

3. Normal. A normal shell is one that approximates the usual shape and that is of good, even texture and strength and free from distinct ridges, rough areas, thin spots, or other conditions not common to good shells.

4. Slightly abnormal. A slightly abnormal shell is one that may be somewhat unusual in shape or somewhat faulty in texture or strength. It may also show distinct but not pronounced ridges, thin spots, or rough areas.

5. Abnormal. An abnormal shell is one that may be decidedly misshapen or decidedly faulty in texture or strength or may show pronounced ridges, rough spots, or other defects.

Terms Descriptive of Air Cell.—Since many variations in air cell are encountered in candling eggs, certain terms are employed to designate each of the different kinds of air cells found.

6. Depth of air cell. The depth of the air cell when in its natural position is the distance from the end of the egg to the plane passing through the egg at the lower edge of the air cell where it touches the shell.

7. Regular. A regular air cell is one that shows a practically even, smooth outline (without any movement) when the egg is twirled.

8. Slightly tremulous. A slightly tremulous air cell is one that retains a practically fixed position in the egg but shows a slight movement, not to exceed ⅛ in., at any one point where its lower edge touches the shell.

9. Movement not in excess of ½ in. An air cell that shows a movement at one or more points where its lower edge touches the shell but not in excess of ½ in.

10. Movement in excess of ½ in. An air cell that shows a movement at one or more points where its lower edge touches the shell which may be in excess of ½ in.

11. Bubbly. A bubbly air cell is one that has several rather small bubbles within or beneath it which give it a bubbly appearance.

12. Free. A free air cell is one that moves freely about in the egg: Such an air cell will seek the uppermost point in the egg, no matter in what position it may be turned.

Terms Descriptive of Yolk.—Eggs vary a great deal with respect to the color and condition of the yolk, the yolk shadow cast, and other matters, so that certain terms are necessary to designate each kind of yolk encountered in candling.

13. Well centered. A yolk that occupies the center of the egg without much movement from that position when the egg is twirled is said to be well centered.

14. Fairly well centered. A fairly well-centered yolk is one that occupies the center of the egg but that may show a moderate movement from that position when the egg is twirled.

15. Plainly visible. A plainly visible yolk or yolk shadow is one that has a plainly discernible outline before the candle and may appear as a dark shadow.

16. Dark shadow. A dark yolk shadow results when a freely mobile yolk closely approaches the shell, when twirled before the candle, and is distinctly discernible as a dark shadow.

17. Outline indistinct. A yolk or yolk shadow, the outline of which is not clearly discernible when viewed before the candle.

18. Outline moderately defined. A yolk or yolk shadow, the outline of which may be seen but is not well defined before the candle.

19. Outline well defined. A yolk or yolk shadow, the outline of which is plainly discernible before the candle.

20. Motion sluggish. A yolk that moves slowly and does not move far from its normal position in the center when the egg is twirled.

21. Slightly mobile. A yolk that moves somewhat but not freely from the center of the egg when it is twirled.

22. Mobile. A mobile yolk is one that shows considerable movement away from the center of the egg when it is twirled before the candle and comes sufficiently close to the shell to cast a decidedly dark shadow.

23. Freely mobile. A freely mobile yolk is one that shows a wide movement or swing away from the center of the egg when it is twirled before the candle and comes sufficiently close to the shell to cast a decidedly dark shadow.

24. Practically free from other defects or blemishes. A yolk that may show a slightly mottled condition but is otherwise unblemished.

25. Other definite but not serious defects. A yolk that is mottled, is slightly spread, or that shows moderate heat spots.

26. Other serious defects. A yolk that is decidedly spread or weak or that shows well-developed heat spots or other spots or areas of a character that do not render the egg inedible.

27. Free from visible germ development. No visible development of the germ indicates that there has been no development of the germ spot or, if slight development has occurred, that it has not progressed to the stage where it can be distinguished by candling.

28. Slightly visible germ development. Slightly visible development of the germ indicates that there has been some development of the germ and that it has progressed to the stage where it is visible before the candle as a deeper colored area on the yolk.

29. Clearly visible germ development. Clearly visible development of the germ without blood showing is a condition that indicates that the

development of the germ has progressed to a stage where it is plainly visible before the candle as a deeper colored area or as a bubble or spot on the yolk.

30. No blood. As used in connection with the condition of the germ, the term refers to blood, the result of embryo development, that shows before the candle. It does not refer to blood spots that occur in fresh eggs not due to embryo development.

Terms Descriptive of the White.—Certain terms are used for the purpose of classifying eggs according to the kind and condition of white that they exhibit when candled.

31. Firm. A firm white is one that is sufficiently thick or viscous to permit but little movement of the yolk from the center of the egg. A firm white is one of the principal causes of an indistinct or a moderately defined yolk outline.

32. Reasonably firm. A reasonably firm white is one that has a weakened viscous condition and thereby allows the yolk to move more freely from its normal position in the center of the egg and to approach the shell more closely when the egg is twirled. When the white is reasonably firm, the outline of the yolk may be well defined, but the yolk does not approach the shell closely enough to cast a dark shadow.

33. Weak and watery. A weak and watery white is one that is thin and generally lacking in viscosity and therefore permits the yolk to move freely from its normal position in the center of the egg and closely approach the shell when the egg is twirled. A weak and watery white is indicated by the free movement and the decidedly dark shadow of the yolk as the egg is twirled before the candle. Eggs with weak and watery whites often develop a tremulous, bubbly, or free air cell.

34. Clear. A clear white is one that is free from discoloration or from any foreign bodies which, before the candle, appear as dark bodies. Prominent chalazas should not be confused with foreign bodies.

Inedible Eggs.—Under the Federal Food and Drugs Act, eggs that are filthy, putrid, or decomposed in whole or in part are adulterated. The following are regarded as inedible eggs: black rots; white rots; mixed rots (addled eggs); sour eggs; eggs with green whites; eggs with stuck yolks; moldy eggs; eggs showing blood rings; eggs containing embryos; and any other eggs that are filthy, decomposed, or putrid.

Inedible or adulterated eggs are not considered as conforming to the requirements of any of the Official U. S. Standards for Individual Eggs.

Eggs containing small meat spots or blood clots of such a character that they can be readily removed are considered edible but not of a quality higher than U. S. Trade, U. S. Trade Dirty, or U. S. Check.

MARKET TERMS FOR PRICE QUOTATIONS

Although the federal standards for individual eggs serve as the basis on which many of the state and other recognized grades of eggs have been established, there are certain terms that do not appear in the definitions of these grades that are used in quoting prices which should be familiar to producers and all others interested in eggs.

Fresh eggs are those which have not been delayed in transit or held to prevent them from qualifying on the basis of quality as equal or superior to the quality represented in the grade of U. S. Extras.

Hennery eggs is a term used by the trade to designate eggs obtained from commercial poultry plants or farms where poultry is given special consideration.

Current receipts constitute eggs as they are purchased from the producer without any selection or grading and may contain small and dirty eggs and even rots.

Rehandled receipts are current receipts that have been sorted, the poorest quality eggs having been eliminated.

Held eggs are understood by the trade to mean eggs that have been delayed in transit to such an extent that they are of lower quality than fresh but have not been held long enough in refrigeration to be classified as "cold storage" or "refrigerator."

Cold-storage or *refrigerator* eggs are those which have been held in cold storage at a temperature of 45°F. or lower for 30 or more days.

Undergrades include all eggs below the best and may be checks, dirties, and others.

MARKETING CONTAINERS FOR EGGS IN THE SHELL

Eggs in the shell are marketed for the most part in cartons, parcel-post containers, and egg cases, the last being by far the most important. These containers should be well made to avoid breakage of eggs and at the same time light enough to avoid excessive shipping charges.

Cartons.—Cartons are pasteboard containers holding ½ or 1 doz. eggs, in the latter case being made in two styles, one holding three rows of four eggs each, and the other holding two rows of six eggs each. Cartons are used in selling eggs direct from the producer to the consumer and by the retail trade. Since the carton of two rows of six eggs each fits into the 30-doz. egg case, it is used much more frequently than the other style. Cartons holding 6 eggs are sometimes used.

Parcel-post Containers.—Parcel-post containers are made in various styles and sizes to hold from 1 doz. to several dozen eggs. They should be durable in construction but light enough to be suitable for the shipment

of eggs by express. Corrugated cardboard and fiber board are satisfactory materials for making-parcel post containers.

Standard Case.—The standard egg case is a 30-doz.-egg-capacity case, with a partition in the center so that each half of the case contains 15 doz. eggs. The cases are light and durable, are easily handled, and because of their light weight do not add much to the total costs of shipping. Cottonwood and spruce are two of the most popular woods used in their make. In packing eggs for shipment the case should be thoroughly nailed with four-penny cement-coated egg-case nails.

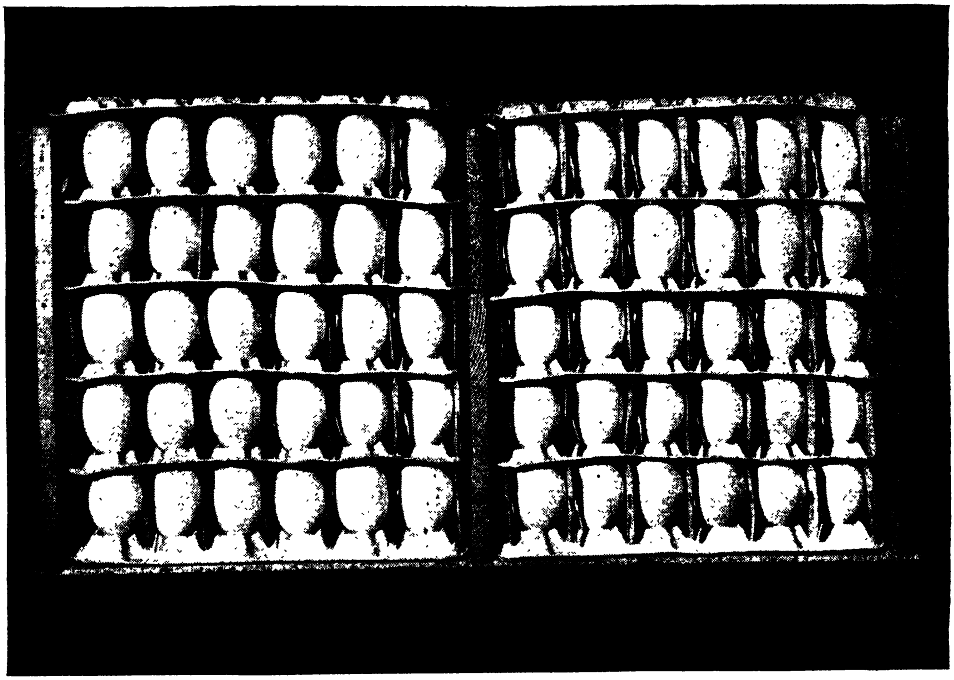

FIG. 172.—The 30-doz-egg case should be of stout construction. Eggs of superior quality packed uniformily always command a premium. (*Keyes Fiber Co.*)

Frequently the cases are branded on the end of the case with a stamped or printed brand of the eggs contained therein.

In packing eggs in the 30-doz.-egg case it is advisable to use egg-case liners, which should be moistureproof and impervious. The use of these egg-case liners prevents the absorption of odors and flavors, retards evaporation of the water content of the eggs, and retains carbon dioxide, thus tending to prevent deterioration in the quality of the eggs.

The packing material used for packing eggs in the 30-doz. case include fillers and flats or the filler flat. These are manufactured in a variety of styles and designs, including the honeycomb filler with flats, embossed flats in which the embossed upper surface provides a center cushion to support the egg, and filler flats which carry eggs without breakage.

In packing eggs in the 30-doz. case care should be exercised to secure uniformity, so that the quality of the eggs at the bottom of the case will be just as good as that of the ones in the top of the case. The eggs should be placed in the case carefully to prevent breakage, long eggs should be tilted slightly to prevent the cracking of the shell, and all eggs should be packed with the large end uppermost. Uniformity of pack increases the chances of commanding the highest prices.

METHODS OF MARKETING EGGS

There are sections of the United States where eggs are produced in excess of local requirements at all times of the year. The Middle West contains about 50 per cent of the total human population and about 75 per cent of the total poultry population. Thus there is a great surplus of eggs produced in those sections of the country where feed is the cheapest. At the same time, there are highly specialized commercial poultry sections on the Atlantic and Pacific coasts which produce surpluses beyond their local requirements, the surpluses being shipped to the larger consuming markets.

The most important egg-consuming centers are located in the highly industrialized sections of the country. The smaller cities throughout all parts of the country secure most of their annual requirements in eggs from the surrounding districts, but the larger ones must rely upon the more important producing areas for their supply. The biggest problem in the transportation of eggs, therefore, is one of transporting the surpluses from the various producing areas to the largest consuming centers.

The methods of marketing eggs from the producer to the consumer are many and varied, depending largely upon the number of channels through which the eggs are obliged to pass before reaching the consumer. The method of marketing employed affects the quality of the eggs as they reach the consumer and the price paid the producer. The more direct the method of marketing the less the eggs have to be handled, the less the delay, and usually the less the cost of marketing.

Direct to Consumer.—Many producers market their eggs direct to the consumer or to a hotel, restaurant, or retailer, this method being followed quite extensively on the part of commercial poultrymen in the vicinity of good markets. Eggs are sometimes delivered by truck or shipped by parcel post, express, or freight. The two important factors that determine whether or not eggs can be sold by the direct method are the ability of the producer to provide a regular supply of high-quality eggs from week to week and the costs of delivering or shipping.

To Country Storekeeper.—Many producers sell their eggs to the country storekeeper or exchange the eggs for goods. This method, however, is gradually being replaced by others more satisfactory. The

country storekeeper is often not in a position to hold his eggs under such conditions as to preserve the superior quality desirable in market eggs. Moreover, most storekeepers do not differentiate between good and poor quality in eggs but pay producers the same price for all eggs received and thus offer the producer no incentive to produce high quality.

Hucksters.—In some sections of the country hucksters gather eggs from farm to farm, a method of marketing having an advantage in being regular as compared with that of producers taking their eggs to the country store any time they wish. Selling eggs to hucksters, however, has the disadvantage that oftentimes no premium is paid for quality. More-

FIG. 173.—Handling and packing eggs in a cool room tend to preserve egg quality. (*Eastern Division, Armour & Co.*)

over, conditions under which many hucksters transport eggs about the country tend to hasten their deterioration.

Local Buyers.—There are local egg buyers located in small towns in practically all parts of the country whose business it is to buy eggs from local sources of supply, collect them in their receiving plants, and pack them for shipment. Since the average shipper does a relatively large volume of business, he is able to buy eggs on a graded basis and thus provide an incentive to the producer to produce good-quality eggs. Unfortunately, however, many local egg buyers do not buy eggs on a graded basis.

Packing Plants.—Throughout the Middle West are located large egg and poultry packers who buy eggs from producers, storekeepers, huck-

sters, and local buyers. Some packing-plant operators use their own trucks, some of which are insulated and carry ice and are equipped with electric fans, for collecting eggs from producers. The egg- and poultry-packing plant thus constitutes the principal concentration agency of a large egg-producing area. The eggs are packed and are then usually shipped in carlots to the principal receiving markets, a carload containing about 400 cases. Cars from the Pacific Coast states usually contain 600 cases. The cars have facilities for ice packing or refrigeration, precooling before loading being very necessary. Because the egg and poultry packer buys eggs in such large quantities, he is able to buy on a graded basis, though very often he does not do so. Buying eggs from the producer on a graded basis stimulates the production of a higher grade of eggs than is otherwise the case.

Jobber or Wholesaler.—Certain producers ship their eggs direct to the jobber or wholesaler located at the terminal markets in the larger cities. Wholesale receivers consist of commission merchants and wholesale dealers, the commission merchant operating on a commission basis, whereas the wholesale dealer buys the eggs and then sells them, taking a chance on a margin of profit. The producer who sells direct to the jobber or wholesale receiver is saved the trouble of establishing and maintaining contacts with the consuming trade, but this method of marketing sometimes returns less to the producer than other methods.

Cooperative Marketing.—In various parts of the United States associations of producers have been formed for the purpose of marketing the eggs of their members. Some of the earliest forms of cooperative egg marketing were egg circles organized in local communities, but in recent years these egg circles have been replaced to a considerable extent by larger cooperative units. Still more recently the cooperative movement has been developed along the lines of egg auctions.

Cooperative marketing organizations must comply with certain government regulations pertaining to membership and management, but they enjoy advantages with respect to the freedom from certain taxes.

The ability of a cooperative egg-marketing organization to operate efficiently and successfully depends upon a number of conditions, including: (1) the *need* for the development of a cooperative marketing method, (2) a sufficient volume of eggs and a sufficient number of cooperators to carry the necessary overhead without undue expense and to permit of securing the most desirable outlets for the eggs, (3) concentrated production to reduce the costs of handling to the minimum, (4) efficient management, and (5) a type of organization that is able to stand the stress and strain of the competitive marketing system.

Some of the largest and most successful egg-marketing cooperatives are those located on the Pacific Coast, in the Rocky Mountain states, and

in the Middle West. During recent years these cooperative associations have marketed upward of 5,000,000 cases of eggs annually.

Illustrative of the service rendered to poultry producers by a sound cooperative marketing organization are the results secured by the Utah Poultry Producers Cooperative Association, one of the largest farmers' cooperative marketing organizations in the United States from the standpoint of volume of eggs sold. Incorporated as a cooperative on a statewide basis in 1923, this association has developed from 3 small receiving stations to 20 egg-receiving and feed-handling stations and 7 additional outlets handling feed and supplies only.

Members of the association sign contracts running for 5 and 10 years, respectively. Besides selling eggs, the cooperative also sells poultry, buys feed and supplies for the producers to whom it sells at cost, and renders other valuable services, including group life and fire insurance. The association has benefited its members very materially through securing higher prices for eggs and poultry than could otherwise have been obtained and by securing feed at lower costs than would otherwise have been possible. Its outstanding achievement has been to encourage the production of high-quality eggs, which have often commanded the highest prices on the New York, Los Angeles, and San Francisco markets, the bulk of the eggs sold by the association being shipped to New York City. The eggs are sold on a graded basis. The fact that eggs are produced in Utah, shipped practically across the continent, and compete successfully with eggs produced in areas adjacent to the New York City market is a glowing tribute of the effectiveness of cooperation conducted on a sound basis.

In some respects the most interesting development in cooperative egg marketing that has taken place in the United States during the past decade has been the formation of country-point egg auctions. They have enjoyed a relatively rapid growth, are located for the most part in the northeastern states, and have been established mostly in areas of comparatively heavy egg production which are within easy reach of the large consuming centers. The auction method of selling enables selling to be transacted at relatively low overhead costs and assures the securing of good prices largely because competition is developed among buyers attending the auction for the purpose of bidding on the eggs being offered. The service rendered by the auctioneer is a very important factor in the success of an egg auction. In most instances the egg auctions have been the means of raising the price level of eggs in the district in which the auction is established.

The auction method of selling eggs was apparently developed largely as the result of the competition on the New York City and other eastern markets of the superior quality eggs produced by the members of the

Pacific Coast and other western cooperative organizations. The fundamental objective in the development of the auction method of selling was to induce the producers in the northeast to improve the quality of their eggs so that higher prices and greater profits might be realized. In most cases the objective has been accomplished to a marked degree.

The eggs are brought to the auction-salesroom where they are inspected by official inspectors and labeled according to grade. The prospective buyer, therefore, has confidence concerning the quality of eggs on which he wishes to bid. The grades set up by the egg auction follow the federal standards closely. The concentration and grading of large volumes of relatively high-quality eggs at central points has made possible the development of an efficient and orderly marketing system combined with low overhead costs.

The success achieved by the auction method of selling has been accounted for by three sets of conditions existing in the area where the auction has been developed: (1) a relatively large volume of eggs produced within a small radius, (2) relative nearness to large consuming centers, and (3) the patronage of a large number of buyers. Under these conditions the auction associations have been able to obtain sufficient quantities of high-quality eggs to attract buyers who have been willing to pay the premium that a high-quality product warrants. Not only has the auction method of selling enabled the producers who sell through the auction associations to obtain higher prices for their eggs, but the average price of all eggs produced in the area has been advanced. Hucksters and local buyers who purchase eggs from nonauction members usually pay prices based on the auction-price quotations.

FACTORS AFFECTING EGG PRICES

The familiar law of supply and demand applies in establishing prices obtained for eggs, although in many cases there may be deviations from the application of this law. Its application is seen in its broadest sense with respect to the seasonal trend in egg production; high spring production is accompanied by low prices, whereas low fall production is accompanied by relatively high prices. During recent years, however, the extremes in spring and fall prices have been reduced materially as the result of many modern tendencies. Earlier hatched pullets, the use of artificial lights to stimulate fall and early winter production, the hatching of pullets in the fall of the year, improved laying ability, better methods of feeding and housing, and holding eggs in cold storage all tend to lessen the wide range between spring and fall prices that formerly prevailed.

There is a definite seasonal trend in the demand for eggs, reaching a peak in the spring during Lent. The consumption of eggs at that time of the year is increased because of the relatively low price and probably

to some extent because of the relatively high average quality of the eggs marketed. The excessive heat of the summer and the offerings of cold-storage eggs on the markets during the fall and winter months have an important bearing on the average quality of eggs marketed during this relatively long period, and, therefore, the consumptive demand for eggs is influenced.

The law of supply and demand operates, to some extent at least, in establishing the price of each grade of eggs marketed. As the quality of

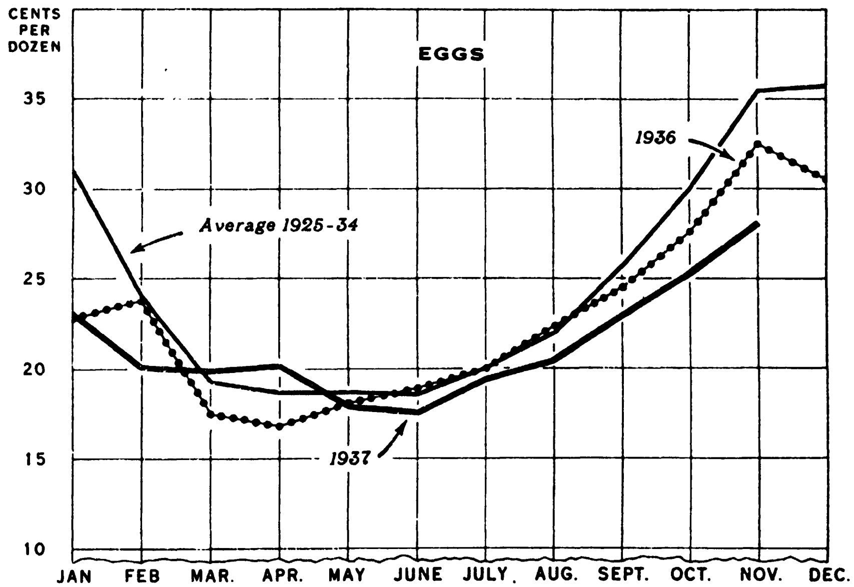

FIG. 174.—Over one-half of the annual egg crop is produced from March to June, inclusive, this being the season of relatively low prices. (*U. S. Dept. Agr.*)

eggs declines during the summer, the price of the poorest eggs is depressed, not only because there is a lowering of quality but also because there is a surplus of these poor-quality eggs. The larger the volume of poor-quality eggs in relation to all eggs marketed the greater the depressing effect on the entire price structure, with the possible exception of a few of the very highest quality grades. On the other hand, if a portion of the lowest grade eggs are inedible and consequently never reach the consumer, the effect on the price structure is influenced by that portion of lowest grade eggs that reach the consumer. At the same time, it should be borne in mind that the marketing of inedible eggs involves wastage as the result of costs in handling and transporting them up to the time they are declared inedible; this wastage adds to the costs of marketing the edible eggs and is borne by the producer, because in the final analysis the price he receives for his eggs is determined in large measure by the average price of all eggs marketed.

Many other factors influence the price that producers receive and consumers pay for eggs, including the cost of grading and transporting, the "apparent" supplies, and the apparent consumptive demands. Factors pertaining to costs in grading and marketing are discussed in the last chapter of this book. As far as the factors of apparent supply and apparent demand are concerned, it may be said briefly that certain situations arise that sometimes affect prices irrespective of the actual supply and demand of eggs. A change of sentiment among buyers and

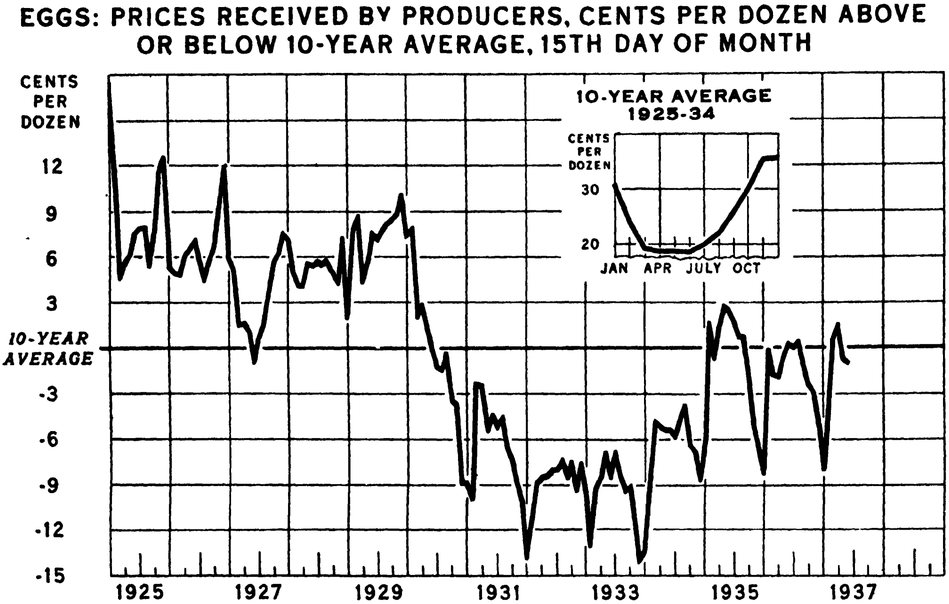

FIG. 175.—Egg prices advanced rapidly in 1935 because poultry flocks were reduced by the 1934 drought and egg production decreased. Increased egg production in 1936 and 1937 caused prices to decline somewhat even though demand was improved. Of primary importance is the change in the seasonal egg prices shown in the chart above. During the years since 1929, the seasonal price advance from spring to winter has not been as great as was the case prior to 1929. Monthly egg prices, shown in relation to 10-year monthly average prices, reveal this fact. The 10-year average price advance from spring to winter is not as great as was the average price advance for years before 1929, so winter prices in those years appear very high. For the years following 1929, the 10-year average price advance is greater than the actual changes which occurred, and winter prices relative to this average are low. (*U. S. Dept. Agr.*)

sellers sometimes lowers or raises prices; a feeling among traders that supplies will not be sufficient to meet anticipated demands leads traders to withhold eggs from the market, with the result that prices advance, whereas if traders feel that if supplies are somewhat more than sufficient to fill immediate apparent demands there may be a tendency to overload the market and cause a lowering of prices. A declining market often causes a further decline which is frequently not justified by the actual supplies available and the actual demand for eggs. Also, a rising market sometimes leads to overenthusiasm on the part of buyers, with the result

that prices rise so high that further demand is affected until a subsequent reduction in price brings about a stabilized price which is in keeping with available supplies and probable demand.

The average price of eggs which producers receive and consumers pay from year to year is affected by the total volume of eggs produced from year to year and by the price of other food products. An excessive supply of eggs one year tends to depress prices during at least a part of the following year, whereas a shortage of supply one year tends to increase prices during a part of the succeeding year. A relative increase in price during one year tends to lead to increased production the following year which in turn tends to depress prices and cause a reduction in the production of eggs the next year. These cycles of rising and lowering prices and production may not occur from year to year but may extend over longer periods than one year. There are many factors, such as a severe drought over a large portion of the country or a very severe winter, that may affect the general trend in prices.

In the marketing of eggs from producers to consumers many wholesalers act as a balancing factor between the forces of supply and demand, buying when there is a surplus and selling when there is a scarcity of eggs. The placing of eggs in cold storage in the spring of the year to preserve their quality during the summer months acts as a balancing factor which tends to minimize the extremes in prices that would otherwise occur. In some of the larger city markets wholesalers sometimes engage in "future" trading, which simply means that they do not buy and sell eggs but buy and sell contracts to receive or deliver cars of eggs meeting certain specifications at a designated future date. This system of trading in "futures" tends to lower the cost of distribution, because it makes possible the transfer of risks and liabilities, less margin being required to cover these risks and liabilities than to cover actual selling contracts.

Many producers are unaware of the method commonly employed in establishing prices, so that a brief statement may suffice to inform them on this point. The egg market of New York City is the largest in the United States and, therefore, serves as the basis for establishing prices in a general way for the entire country. A thoroughly qualified egg reporter makes daily visits to the New York Mercantile Exchange, where traders buy and sell eggs, learns the egg receipts reported during the day, discusses with traders the market conditions, and determines the influence of the "bulls" and the "bears" by the offerings and the biddings as they are made. From the Exchange the reporter goes to visit the egg dealers on the street and after getting their combined opinion of the market situation reaches an opinion as to what he thinks are the correct market values for the day. His estimated values apply to eggs that are in the

hands of the first receivers and include the costs of selling and of shipping by freight or truck, as well as other costs involved in getting the eggs from the first receiver to the jobber. The country shipper expects to get the market quotation minus the costs of shipping and delivering the eggs.

EGG-CONSUMPTION PROBLEMS

Practically all people have a marked preference for fresh eggs. At the same time, eggs kept in the kitchen of the farm home for several days and then held in a country grocery store for a week or so may be distinctly inferior in quality to eggs held under proper conditions of storage for 6 months, provided the latter were of good quality when placed in storage. The California Experiment Station has shown that the percentage of thick white in eggs taken out of storage is proportional to that in the eggs when they were placed in storage. In other words, eggs of poor quality at the time of being placed in storage deteriorate more rapidly during storage than those of good quality. Nearly all eggs that have been held in storage possess a flavor that is not characteristic of the strictly fresh egg.

As the result of the all too frequent practice on the part of dealers of misrepresenting storage eggs as fresh, several states, especially in the Northeast, have adopted what are known as "fresh-egg laws" the principal intent of which is to insure consumers' being able to buy eggs of known quality. When intelligently administered these laws have had the effect of encouraging producers to take more interest in the production and marketing of eggs of improved quality and have tended to discourage misrepresentation by dealers. If unwisely enforced, however, the fresh-egg laws tend to discourage dealers from offering fresh eggs as such, and egg consumption may be curtailed.

Strictly fresh eggs are particularly desirable for serving as fried, soft cooked (commonly but mistakenly called "soft boiled"), and poached eggs as well as for practically all cooking and baking purposes. Workers at the Washington Experiment Station have shown that fresh eggs having a high albumen index present a better appearance when fried and poached than those with a low index. Although it has been shown that in eggs having a relatively high proportion of thin white the whites usually beat faster than the whites of eggs having a relatively high proportion of thick white, it has also been shown that the foam obtained from beating thick whites is usually more stable than that obtained from beating thin whites.

Several studies have been conducted in different parts of the country with a view toward determining the preference of consumers for eggs possessing certain qualities. For the most part the results of these studies have shown that consumers as a whole know very little about the

characteristics of an egg that make for quality, although the majority of them expressed a desire for eggs of good quality. They attach considerable importance to size but are most particular about interior quality, being willing to pay a few cents per dozen more for a superior grade as defined by the retailer. On the other hand, lower quality eggs are given a preference by some families entirely because of their lower price.

In several cities a preference was indicated for eggs with white shells, whereas in other cities the reverse was true. In many cases it was learned

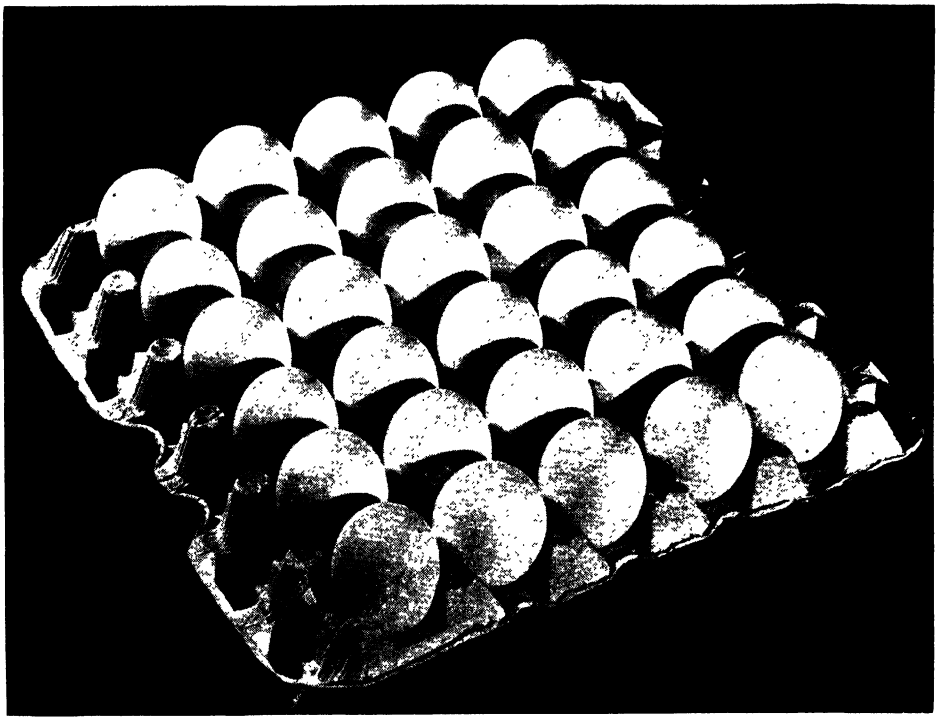

FIG. 176.—Appearance counts a lot with purchasers, who prefer good sized eggs of high interior quality. Uniformity of appearance and quality tends to increase sales. (*Keyes Fiber Co.*)

that white eggs were preferred because it was assumed that light-colored yolks were associated with white shells. In so far as known there is no difference in the nutritive value of white and brown eggs.

In some cities a majority of the consumers expressed a preference for eggs containing light-colored yolks, whereas in other cities many expressed a preference for medium- or dark-colored yolks. Regardless of the preference for a particular shade of yellow, it is obvious that when two eggs are served together the yolks should be of an even shade.

The odor and flavor of eggs are matters that have received relatively little attention, although they constitute a very important field of study. Storage eggs of low quality, whether because of their poor quality when

placed in storage or because of improper storage conditions, usually have a strong odor and pronounced flavor when served as soft-cooked eggs. Workers in the U. S. Department of Agriculture have shown as the result of a study in the flavor of stored oil-treated eggs that fresh eggs scored much higher in taste tests than oil-treated, stored eggs, although the oils used were shown to have no effect on flavor. It was further shown that the higher the grade of stored egg the higher the scoring taste, on the average.

Taste studies conducted for the purpose of determining differences in the flavor of eggs have demonstrated very clearly that taste is a sensory factor the intensity of which is not clearly defined. In making such studies great care should be exercised to select tasters with well-developed, sensitive taste buds and no personal prejudices concerning the kinds of eggs being tasted. The studies that have been conducted make it clear not only that these points should be taken into consideration but also that it is very important to develop standards for egg flavor.

From the standpoint of their nutritive value, eggs occupy a unique position in the human dietary. They serve a very important role in the baking and cooking industries and can be used in combination with other foods as well as by themselves in a great variety of ways. Frozen and dried egg products are being used more extensively as time goes on, and many new dishes have recently been developed in which eggs in the shell constitute the major part.

The egg is an excellent source of protein, fat, and certain minerals and vitamins. Because of peculiar properties of the proteins in eggs they are extremely useful for thickening, for leavening, and for clarifying soups. They are invaluable in the making of custards, frostings, and mayonnaise. The egg is relatively rich in iron and phosphorus, and it is also an excellent source of vitamins A, B, G, and D. Because of these properties and because it can be so readily prepared for human use, there is every reason to believe that egg production will assume increasing importance as a branch of agriculture.

The production of eggs per capita of the human population has more than doubled during the past 50 years in spite of the fact that the human population has increased two and one-half times. In other words, human population has increased 2.5 times, whereas egg production has increased 5.0 times. During the past few years the per capita consumption of eggs has been estimated to be about 23 doz. per year, but recent studies have indicated that apparently the actual consumption is probably in the neighborhood of about 25 doz. per capita. Increased per capita consumption in the future will in all probability be determined to a considerable extent by the improvement in the average quality of all eggs that are marketed.

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CHAPTER XII

POULTRY-MARKETING PROBLEMS

Concerning the manifold problems that face the poultry industry, in many respects there is probably more need for the improvement in the quality of poultry meat offered to consumers and in the methods of marketing poultry than pertains to most other problems. Because the production of eggs has contributed more than one-half of the total poultry receipts obtained from the average farm- and commercial-poultry flock, the various factors that affect the quality of poultry meat and the economic factors involved in the methods of marketing poultry have suffered at the expense of the attention that has been given to problems of egg production and marketing.

Chickens are marketed in a variety of ways including alive, fresh-killed dressed, fresh-killed drawn, storage dressed, slow-frozen drawn, and quick-frozen drawn. The marketing of live poultry, involving as it does the shipping of live birds several hundreds or thousands of miles, represents an economic wastage of large proportions, because transportation charges must be paid on the heads, feet, and offal; hauling live-poultry cars and live-poultry trucks involves needless expenditures; and the costs of dressing poultry in terminal markets are usually greater than at producing centers. Even the marketing of dressed poultry involves economic wastage, since transportation charges have to be paid on heads, feet, and offal, and the costs of "drawing" the chickens in the retail shops of the larger cities are usually greater than at the producing centers. It seems quite probable, however, that for many years to come a certain proportion of the chickens raised every year will be marketed alive.

QUALITY IN LIVE POULTRY

The palatability of poultry meat is a deciding factor in determining its demand by consumers and the price they are willing to pay. Palatability is a measure of quality in poultry meat, this quality being determined by such factors as the breeding and feeding of the birds, their age, and methods employed in preparing them for market as well as those employed in marketing.

The effects of breeding and feeding on the quality of live poultry have already been discussed in preceding chapters so that only a few illustrations need be given here by way of review. The lighter breeds of chickens are not so highly regarded as meat producers as the general-

purpose breeds. Crossbreeding strains of superior quality frequently results in a faster rate of growth during the first 12 weeks or so and in many cases in a better finished carcass. The rate and condition of

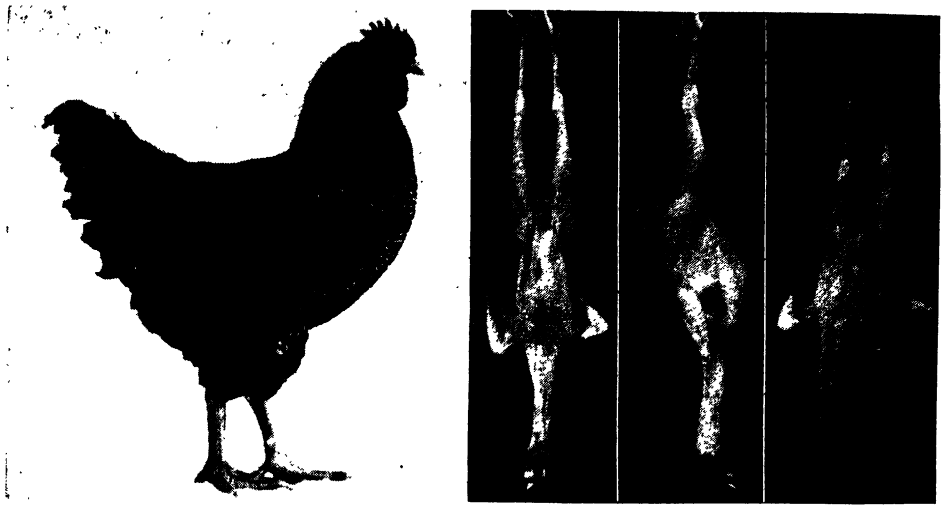

FIG. 177.—Dressed birds of superior type and finish can be secured only from live birds of the proper type and possessing good fleshing properties. This Barred Plymouth Rock cockerel is shown alive at 26 weeks of age together with three views of his dressed carcass. (*Maw*, 1933.)

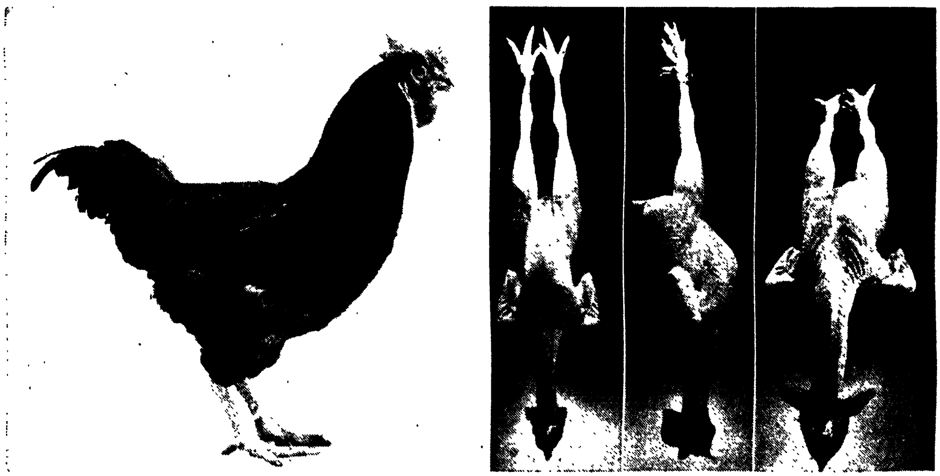

FIG. 178.—The body type of the live bird has a direct bearing on the finished appearance of the dressed carcass, as shown by this Rhode Island Red cockerel at 26 weeks of age. (*Maw*, 1933.)

feathering are largely a matter of proper breeding, poor feathering over the back being an undesirable market characteristic. The shape of the bird is a matter of heredity and is of importance from the standpoint of the amount and distribution of fleshing. At Macdonald College it has been demonstrated that birds with long keels and relatively long bodies

are more inclined to have crooked keels than birds with shorter but wider bodies.

The diets used and the methods of feeding employed in feeding chickens have an important bearing on quality in live poultry. Undernourished chickens are invariably thin and scrawny. Diets lacking in minerals and vitamins and diets that are not properly balanced with respect to calcium, phosphorus, and other nutrients frequently produce skeletal deformities, retard growth, and affect fleshing properties. Certain kinds of diets may affect the color of the flesh and the flavor of poultry meat, these factors of quality being revealed when the chickens are killed and dressed.

Other factors affecting quality in live poultry include parasitic infestation and disease infection. Chickens heavily infested with worms are liable to be thin and may become lame. A common cold and many other diseases frequently result in poor fleshing. Rough handling during shipment may result in body bruises.

In these and in many other ways is the quality of live poultry affected adversely, and it is of the utmost importance that every poultry producer take the greatest possible precautions in rearing chickens that attain the highest possible grades.

GRADING LIVE POULTRY

Producers should appreciate the fact that live poultry graded according to weight, age, and condition usually command a higher price than ungraded poultry. The Bureau of Agricultural Economics of the U. S. Department of Agriculture has proposed tentative classes and subclasses for live poultry, the classes being roasters, fowl, etc. For each class the bureau has proposed three grades, and in addition birds that are regarded as unfit for food are graded as "rejects," the specifications, revised Apr. 1, 1937, of the four grades being as follows:

U. S. Grade A.—Vigorous birds, well-fleshed, plump and full feathered, with bright red combs and soft glossy skin. Must be soft meated for birds of that class and free from tears, bruises, and deformities. Excess abdominal fat and broken bones are not permitted and the birds must be free from external evidence of disease. A tolerance of 24 per cent of the birds in the lot is permitted for birds of U. S. Grade B and 1 per cent for birds of U. S. Grade C.

U. S. Grade B.—Fairly well-fleshed birds, fairly well feathered, free from tears, bruises, or deformities. Broken bones are not permitted and the birds must be free from external evidence of disease. A tolerance of 25 per cent of the birds in the lot is permitted for birds of U. S. Grade C.

U. S. Grade C.—May be poorly feathered birds, poorly fleshed but not emaciated. Carcass may show a few scratches, tears, or bruises. Deformed birds permitted if fairly well fleshed. Not more than one broken bone permitted. Must be free from highly infectious diseases. No tolerance is permitted for birds that are below that of U. S. Grade C.

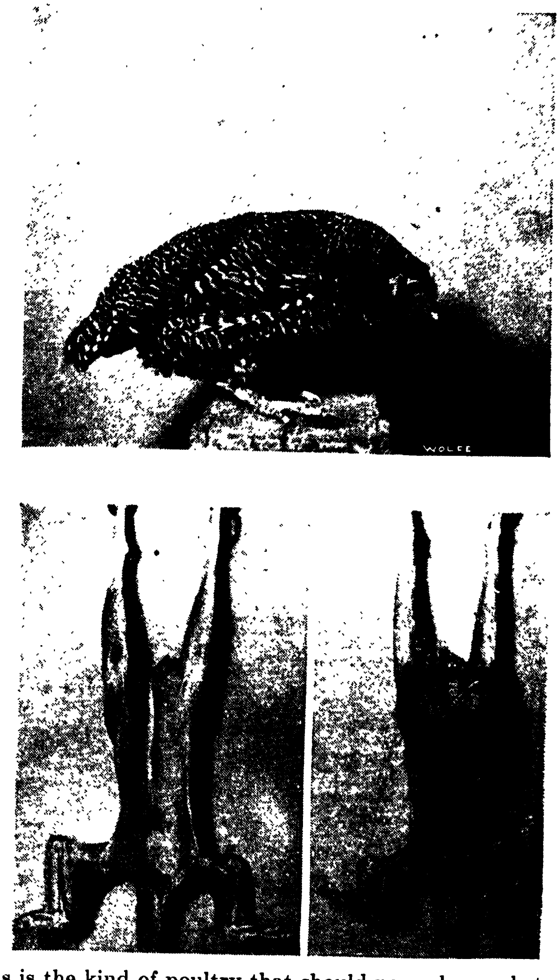

FIG. 179.—This is the kind of poultry that should never be marketed. The specimen shown is termed a "reject" and is of extremely poor quality. (*U. S. Egg and Poultry Mag.*)

Rejects.—All cull birds must be graded as Rejects. Rejects include all birds that show evidence of a sick condition, severe injury, extreme emaciation, cripples, crop bound, or other conditions that render them unfit for good. Birds afflicted with the following diseases are classed as Rejects: (1) roup (catarrhal and diphtheretic), (2) infectious bronchitis, (3) fowl cholera, (4) fowl typhoid, (5) limberneck, (6) tuberculosis, (7), water belly (ascites).

TABLE 54.—TENTATIVE U. S. CLASSES FOR LIVE POULTRY
(U. S. Department of Agriculture, Apr. 1, 1937)

Classes	Breed subclasses	Weight classes	Description
Chickens...	Barred Rocks Other heavy breeds Light breeds	Small—under 2½ lb. Medium—2½ to 3½ lb. Large—over 3½ lb.	Young, soft-meated chickens of either sex, with flexible breastbones
Stags.......	All breeds	All weights	Young male chickens that have begun to get hard meated and coarse and showing well-developed comb and spurs. Breastbones becoming rigid
Capons.....	All breeds	Small—5 lb. and under Large—over 5 lb.	Unsexed male birds showing practically no comb or spur development and with profuse tail, saddle, and hackle plumage
Fowl.......	Heavy breeds Light breeds	Small—under 4 lb. Medium—4 to 5 lb. Large—over 5 lb.	Mature female chickens with hardened breastbone
Cocks......	All breeds	All weights	Mature male chickens with hardened breastbone

This table indicates that weight according to age is an important factor in the grading of live poultry, being influenced not only by skeletal dimensions but also by the amount of fleshing. Birds 1 year old and over are classed as fowl or cocks, depending upon the sex. Except for capons, birds under 1 year of age are classed as chickens or stags, the last two classes being determined largely by the age of the birds.

METHODS OF MARKETING LIVE POULTRY

Crates of various designs are used for shipping live poultry. Each crate should be of a sufficient size to accommodate about 12 to 20 chickens. Too many chickens should not be placed in one crate, because some might be suffocated. The crates should be as strong but as light as possible in order to save shipping charges. Different types of crates are used, one being 2 ft. wide and 3 ft. long, one 12 in. high, another the same width and length but 16 in. high, still another being somewhat wider and longer.

Live chickens are marketed by producers in their own wagons, trucks, or automobiles to local buyers and poultry-packing plants or are shipped by express, freight, or truck to distant markets. Whatever may be the

practice followed, great care should be taken to see that the chickens are crated and shipped in such manner as to ensure their arrival in the best condition possible.

In many cases live chickens are sold direct from the farm to a huckster or to a local buyer who sends his truck around to farms and, upon securing a truck load, frequently delivers it many miles to a distant market. In these cases the shipper should exercise the greatest care in crating the poultry and arranging the crates in the truck in order to keep the chickens comfortable during the voyage to market.

Chickens in crates being taken to market in trucks, automobiles, or wagons should not be subjected to cold winds lest some of the birds catch cold; nor should they be allowed to become overheated.

Shipping by Express.—Many producers find it to their advantage to ship live chickens by express to distant markets rather than selling locally. When chickens are shipped by express they should be graded in the crates according to color, age, size, and condition. Chickens crated according to color always command the buyer's attention more readily than crates of chickens of various colors. Chickens graded according to age and size always have a market advantage over those not so graded. Old birds should never be mixed with young ones, and very small birds should not be crated with very large ones. Grading the chickens according to condition is an important factor in commanding the best prices. Cull chickens and those that are sickly should never be shipped to market. Chickens that are in the best fleshing condition should be crated together, leaving the poorly fleshed ones to be crated by themselves.

Producers should study the live-chicken-market requirements of the market to which they ship their chickens in order that the best shipping days may be determined. Live chickens should not be shipped to arrive at the market on Saturday afternoon, because they usually have to be held over until Monday, in which case there is usually excessive shrinkage in weight. Sometimes advantage can be taken of the higher prices prevailing for live chickens at the time of the Jewish holidays.

A certain amount of shrinkage in weight usually takes place when live chickens are shipped to market, the amount of the shrinkage depending upon the shipping distance and the season. The customary amount of shrinkage ranges from about 2 to 15 per cent or more of the original shipping weight, chickens shipped short distances losing less than those shipped far away.

Where live chickens are shipped such distances as to require 24 hr. or more before reaching the market, a tin of corn that has been thoroughly soaked in water may be nailed on the inside of the crate. The water-soaked corn helps to prevent excessive shrinkage. In the case of chickens arriving on the market the same day they are shipped they should not be

fed during transit but may be fed a few hours before being crated for shipment. Chickens arriving on the market with crops full of feed usually bring a lower price than otherwise, or they may be held over until the feed is digested.

Shipping by Freight.—Freight shipments of live chickens are made either in livestock cars or in specially constructed live-poultry cars. The live-poultry car is by far the most satisfactory method of shipping chickens by freight.

Most shipments of live-poultry cars originate at the poultry-packing plants, this being the customary practice throughout the Middle West. Some shipments of live-poultry cars are made up at railway stations along

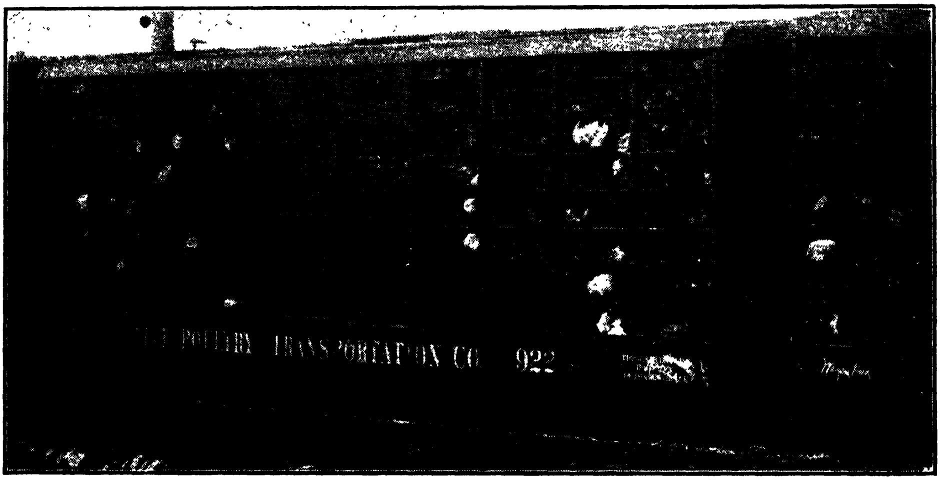

FIG. 180.—Live poultry on its way to New York. (*U. S. Egg and Poultry Magazine.*)

a prescribed route where producers bring their chickens to the nearest station, this practice being followed in certain southern states where there are but few poultry-packing plants.

A live-poultry car is constructed with compartments or coops from the floor to the roof on each side of a center aisle. Each compartment is provided with a feeding and watering trough and with a removable bottom for ease in cleaning. The outside of the car is covered with heavy wire screening, and in bad weather a canvas should be used to provide protection. There is a small room in the center or at the end for the attendant, and some cars are provided with a heating system for heating the different parts of the car. There are usually 128 compartments in a car, which will accommodate about 4,800 chickens weighing approximately 16,000 to 18,000 lb. net.

Since chickens may be in transit in a live-poultry car for 2 or 3 days to a week or more, they must be fed in order to reduce shrinkage. Feeding is practiced in much the same manner as in feeding chickens in the

packing house, which has been discussed in the chapter on feeding practices. Upon arrival in the New York City live-poultry terminal market the crop should not contain more than 2 oz. in weight of feed, according to a regulation of the Department of Health of the city. Federal inspection is provided to see that the crops are not overloaded with feed.

Shipping by Truck.—The shipment of live poultry by truck has increased considerably during recent years, both for long- and for short-distance hauling. The chickens are picked up in the producing areas. The trucks vary in size and in the number of birds that can be accommodated, some having eight tiers of compartments from floor to roof on each side of a center aisle.

TABLE 55.—RECEIPTS OF LIVE POULTRY AT NEW YORK CITY, BY FREIGHT, EXPRESS, AND TRUCK, 1925 TO 1935[1]
(Sprague, Sturgess, and Radabaugh, 1937)

Year	Cars				Year	Cars			
	Freight	Express	Truck	Total		Freight	Express	Truck	Total
1925	10,498	840	475[2]	11,813	1931	10,152	285	1,498	11,935
1926	11,497	752	575[2]	12,824	1932	9,126	160	2,048	11,334
1927	12,104	934	700[2]	13,738	1933	8,150	113	2,317	10,580
1928	11,267	937	850[2]	13,054	1934	7,641	112	2,428	10,181
1929	10,493	674	1,050[2]	12,217	1935	5,387	137	3,157	8,681
1930	10,677	476	1,386	12,539					

[1] To convert to pounds, multiply by 16,000.
[2] Estimated.

Terminal-marketing Methods.—When a shipment of live poultry arrives at the terminal markets in the larger cities it passes through several hands before reaching the consumer. In the smaller terminal markets the shipment is usually transferred by the receiver or commission man to a wholesaler who in turn sells it to a retailer or slaughterhouse operator. In some cases the receiver may have the shipment sent to his own killing establishment. In some of the larger terminal markets, such as New York City where there is such a large Jewish population, the shipment is unloaded at an unloading center and transported to the slaughterhouse for killing. From the slaughterhouse the dressed birds are transported to dealers.

Since New York City is the largest live-poultry terminal market in the country, and since live-poultry prices in New York City determine to some extent the prices paid for live poultry in all other parts of the country, it is well to consider very briefly some of the more important factors involved in the handling live poultry in such a large city as New York.

There are three classes of live-poultry dealers in New York City: the commission merchant, who acts as an agent for the shipper or buys poultry outright in wholesale lots and sells in job lots; the slaughterhouse operators, who buy live poultry and slaughter and deliver in small lots; and the live-poultry retailer who maintains a retail slaughterhouse, or chicken "stand," in a public market where the consumer selects a live bird which is then killed and dressed.

The numerous details involved in the unloading of shipments of live poultry, cooping and uncooping the birds, and holding and handling in the slaughterhouses and in the retail stores have made it possible for many abuses to arise. Some of these abuses include excessive charges for unloading, charging for coops when no coops were used, recording incorrect weights, and many other acts of injustice practiced by different groups of dealers. Because of lack of space, it is impossible to discuss these problems in a book of this kind, but it is important to note that as the result of many unfair trade practices that existed in the marketing of live poultry in New York City, officials of the U. S. Department of Agriculture conducted an economic survey of the live-poultry industry and made numerous suggestions with respect to the improvement of conditions.

Dealers in live poultry in New York City and several other large cities, as may be designated by the Secretary of Agriculture, are required to obtain a license under the Packers and Stockyards Act. Receivers of live poultry are required to file tariffs of their rates and charges, and the Secretary is given power to regulate dealers and handlers of live poultry where unfair, deceptive, and fraudulent practices are found to exist.

KILLING, DRESSING, AND COOLING

Producers who sell direct to consumers or on the public markets of the larger cities usually sell their chickens dressed rather than alive. Also, except for the demand for live chickens for the Jewish trade and certain other people who demand fresh-killed chickens, most of the chickens shipped to the markets of the consuming centers are shipped in the dressed form. A dressed chicken means, of course, one that has been killed and plucked.

Dressed chickens are shipped either in the fresh condition or after they have been held in storage for some time. In recent years dressed chickens that are drawn and frozen immediately after being dressed have been shipped direct to retailers and consumers.

Bleeding.—Chickens should be deprived of feed for about 24 hr. before being killed. This will empty the crops and intestines of feed. The dressed birds also will keep longer and will be of better quality.

During the period when they are not fed they should have water, which will wash feed particles out of the digestive tract.

One of the best ways to kill a fowl is to bleed it by severing the arteries in the neck. From the ceiling of the room in which the killing is to be done the fowl is suspended by the feet at about the height of the shoulder of the plucker. Any stout cord with a short stick in the end will do to wrap around the bird's feet. In poultry-packing plants shackles made of stout wire are used.

A particular kind of killing knife is desirable. The blade of the knife is a heavy piece of steel, about 2 in. long, 1/4 in. wide, and 1/8 in. thick on the back. It should be ground to a sharp point with a straight cutting edge, the slope of the point being taken from the back rather than from the front edge. The handle should be fairly stout, so that it can be grasped readily. A strong, sharp jackknife could be used to advantage.

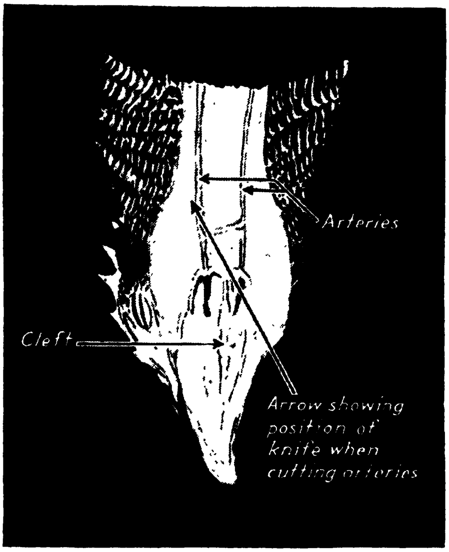

FIG. 181.—Showing the proper method of bleeding a chicken. (*Dominion of Can. Dept. Agr.*)

The head of the fowl is taken in the left hand, and the knife in the right. With the thumb and forefinger of the left hand the mouth is forced open by pressure, and the knife is inserted with the blade pointing toward the back of the head. The knife is then forced up to the juncture of the head and neck where the arteries come down on each side of the neck; these are severed, and the fowl bleeds freely. A left-handed person would perform the operation in the opposite way.

The loss of blood amounts to about 4 per cent of the weight of the bird.

Piercing the Brain.—Immediately afterward the knife is forced into the roof of the mouth. This is done by withdrawing the knife from the juncture of the head and neck and turning it over so that the back of the knife passes along the upper beak into the groove in the roof of the mouth. It is then immediately forced into the brain cavity so that the brain is pierced. When this is done properly the bird will squawk, and it will also make a convulsive movement which tends to loosen the feathers in the feather follicles. If the brain has not been properly pierced the feathers are hard to pluck, and the skin is frequently torn badly. Poorly bled chickens frequently show reddened areas over the body, especially along the neck and around the thighs.

There has recently been developed a machine that electrocutes the birds, 120 volts being used, and then automatically severes the jugular veins from the outside rather than through the mouth, as is the custom in hand killing.

For the Jewish Trade.—Chickens killed for the orthodox Jewish trade must be slaughtered under the supervision of a rabbi, such chickens being known as "kosher killed." One of the essential features in kosher killing is that both the jugular vein, esophagus, and the trachea must be severed. After the chicken's throat has been cut, the killer must pass his thumb forward from the rear of the neck to push out the end of the trachea to be sure that this has been completely severed. To remove the knife from the cut and replace it makes the chicken nonkosher. Diseased chickens and those having broken bones are not acceptable for kosher killing.

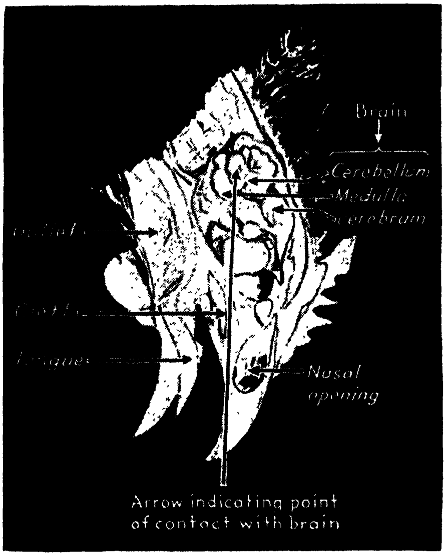

Fig. 182.—Showing the proper method of piercing the brain in order to make plucking easy. (*Dominion of Can. Dept. Agr.*)

The ritual of slaughter is performed by a shohet who is certified by a rabbi. The Talmud gives the numerous details of the act of ritual slaughter.

A Jewish supervisor, called the "mashgiach," places a plumba, or small metal band, on birds that are properly killed and are, therefore, suitable for the Jewish consumer. The consumer must follow certain prescribed practices in preparing fresh-killed poultry for the table, including soaking and salting for the purpose of drawing all blood from the meat.

Dry Plucking.—For many years the most common method of plucking chickens was by dry plucking, the body feathers being removed by a rubbing motion of the hand, and the tail and wing feathers pulled out. Dry picking must be done the moment the bird is killed and while the body is still warm. The feathers are plucked in the following order: tail, large wing feathers, breast and sides, thighs, legs, soft body feathers, back feathers, neck and small feathers on the wings, and hip feathers. The birds should then be hung on racks in a chilling room as near freezing as possible, but not below 32°F., for at least 24 hr. before being packed.

During recent years an automatic dry-plucking machine has been developed and has been used extensively in France, England, and other

countries. The machine consists of a high-speed suction fan operated electrically and high-speed revolving plucker plates driven by the same motor. The bird is held before the machine in such a way that the fan blows up the feathers while a series of steel plates, which come together on each revolution, plucks them very rapidly. Pinfeathers on the wings and thighs usually have to be removed by hand.

The feathers constitute about 7 per cent of the live weight of the bird.

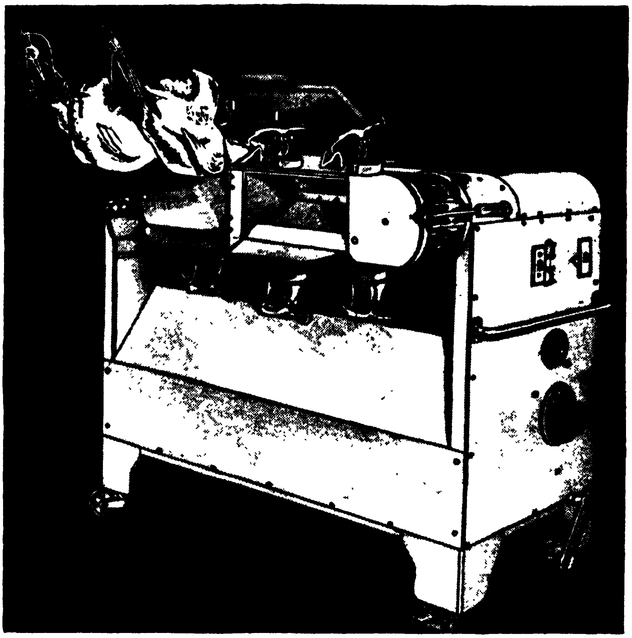

FIG. 183.—A modern electrocuting and bleeding machine used for the preparation of poultry for plucking. (*Barker Poultry Equipment Co.*)

Hard-scald Plucking.—The feathers are plucked quite readily if the birds are dipped for a few seconds in water kept at a temperature of 180 to 190°F. The head and feet are usually not immersed, so that they retain their natural color. If the water is too hot the skin will have a scalded appearance. The hard-scald method, though used for plucking chickens for home use, if carefully done can be used for marketing dressed birds direct to the consumer in a local market. Even when hard scalding is properly done the skin rarely has the desirable appearance seen in dressed birds plucked by other methods.

Semiscald Plucking.—For slack scalding or semiscalding the temperature of the water should be 128°F. for broilers, 129°F. for chickens, and 130°F. for fowl, and the birds should be kept in the water for 30 to 35 sec. In large poultry-killing establishments the birds are killed by hand and then are transported by an endless chain to the water tank

into which they are automatically dipped and withdrawn. The feathers are picked off, the skin usually having practically as nice a finished appearance as in dry plucking. Moreover, there is less danger of tearing the skin, and the pinfeathers are more easily removed.

Wax Plucking.—Dipping birds in melted wax facilitates plucking and removes the hair and the pinfeathers, thus having several advantages over all other methods of plucking. Wax plucking may be used in conjunction with dry plucking or with the semiscalding method. A special kind of wax is necessary.

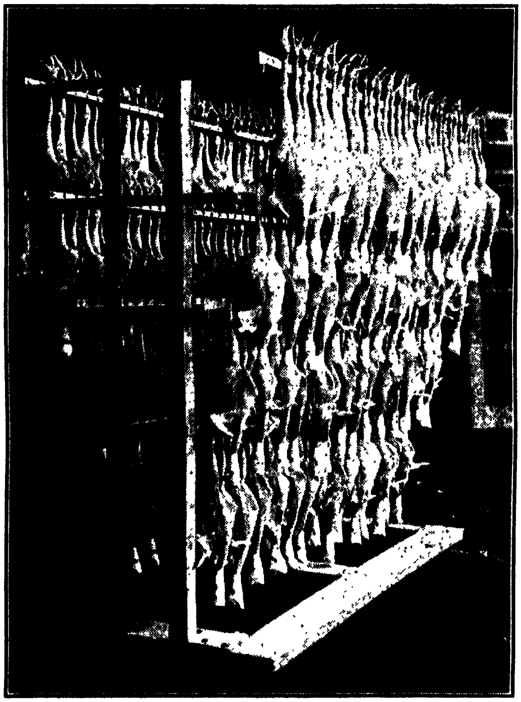

FIG. 184.—Dressed chickens with heads wrapped, suspended on a cooling rack. (*U. S. Dept. Agr.*)

Wax plucking combined with dry plucking has been tried with partial success for plucking chickens on the farm for selling on the local market. The wax should be melted about 1 hr. before the birds are dry roughed and the molten wax should be kept at about 130°F. The proper temperature is maintained by placing the pail or kettle of wax in a larger vessel of warm water, hot wax being added from time to time. The birds are rough plucked immediately after being killed and are hung up in a moderately cool room to allow body heat to escape until the temperature of the carcass is about 70°F.

Each carcass is then individually plunged into the molten wax and agitated for about 5 sec., then withdrawn and held over the molten wax

until there is no dripping, this process being repeated three times. If the temperature of the wax is a little below 130°F. two dippings may be sufficient, but if it is somewhat higher than 130°F. four or five dippings may be necessary to build up a good coating of wax. After the carcass has been dipped a sufficient number of times, it is hung up to allow the wax to harden, about 15 min. being sufficient. It is then dipped in cold water for from 30 to 60 sec., and the wax is removed. The wax should not be allowed to become too hard, or it will be difficult to remove and may lead to torn skin. It should be reclaimed by melting and straining to remove the feathers. Very pinny birds and molting hens

FIG. 185.—Wax plucking. A modern poultry dressing room is operated efficiently, and the greatest care is taken to give the birds the best possible finished appearance. (*U. S. Egg and Poultry Mag.*)

are not suitable for wax plucking after dry roughing. There is still need for improving various details of wax plucking on the farm before it will be entirely successful.

Wax plucking in conjunction with semiscalding is used extensively in the commercial dressing plants and has been found to remove practically all pin feathers. The temperature of the wax should be about 125°F. Immediately after the birds are semiscalded they are dried by being run on an endless chain through drying chambers. Upon emerging from the drying chambers the carcasses are automatically suspended by the head and feet and are carried on the endless chain to the receptacles containing the melted wax into which they are dipped once or twice, usually twice.

After they are dipped in the melted wax they are run through chambers in which they are sprayed with cold water to harden the wax, after which the wax and feathers are removed by hand. The wax is reclaimed

for further use. In commercial poultry plants, wax plucking appreciably reduces costs over other methods and produces a much better looking dressed bird, on the average.

Dressing Details.—Soiled heads, feet, and vents should be cleaned thoroughly in order that the dressed birds may present an attractive appearance. The heads should be wiped with a damp cloth, the feet scrubbed with a brush and then wiped with a dry cloth, and the vents squeezed to remove fecal matter to avoid soiling when the birds are packed in boxes. The dressed weight of fattened roasters averaging 5 lb. each constitutes approximately 89 per cent of the live weight.

Feed should be removed from the crop, to prevent the development of sour crop. The feed is removed by pressing the hands downward around the neck from the crop to the mouth or by making a slit along the backbone and removing the contents through the opening or, better still, removing the crop and its contents. Cutting the skin of the bird is decidedly objectionable, however, because it is liable to give rise to spoilage if the birds are held for any length of time.

The heads should be wrapped in parchment, brown kraft paper, or, better still, brown kraft paper waxed on one side. One end of the wrapper is cut on the diagonal, which makes it possible to wrap the head very neatly.

Cooling.—The body heat should be allowed to escape as soon as possible after the birds are dressed, cooling to a temperature of 32°F. being desirable. Cooling by immersing the birds in cold water for 5 to 10 hr., is practiced to some extent although dressed birds so cooled tend to deteriorate more readily than when dry cooled. If the temperature of the killing room is below 32°F. it is possible to cool dressed birds by hanging them up for several hours, provided they are being marketed locally. For commercial marketing the dressed birds should be cooled by mechanical refrigeration at temperatures ranging from 30 to 34°F.

PRESERVATION OF QUALITY IN DRESSED POULTRY

The quality of dressed poultry is determined by the quality of the birds before being killed and by the methods employed in killing, dressing, and cooling. Quality in live poultry has been discussed previously; suffice it to say here that dressed birds of superior quality are well meated and plump breasted, with the flesh well distributed over the body, giving a fine finished appearance. The keels are perfectly straight, and the carcasses are of good breadth in relation to length.

The carcasses should be free of any blemish or defect, such as torn skins, bruises, or deformities, and there should be freedom of pinfeathers.

Discoloration resulting from improper bleeding is a serious defect. If the bird is improperly bled the skin over the hips, legs, and neck is usually quite red in color, and the crop often appears dark, as the result of blood having been swallowed.

The proper preservation of quality in dressed poultry is of the utmost importance in order that consumers may be supplied with poultry meat in its most palatable form.

Freezing Dressed Poultry.—After the dressed birds are cooled in a temperature of about 32°F., they should be frozen in order that the meat may be kept in the best possible state of preservation. Dressed birds that are to be stored for any length of time are carefully sorted as to size and quality and then placed in the freezing rooms. Freezing the poultry as quickly as possible is most essential, and holding the frozen product at a temperature as low as zero is desirable. Lower temperatures have been tried with success, but the cost of holding increases greatly as the temperature is lowered.

The observation that desiccation often occurred in hard frozen poultry led to the further observation that a low, uniform temperature is desirable in order to maintain the proper humidity in the atmosphere of the freezing room. The optimum humidity for frozen poultry has not been determined, although it has been shown that moisture sprayed by power atomizers into the freezer rooms until snow covers the boxes of poultry and hangs from the ceiling prevents desiccation.

The experience of many cold-storage operators has shown that widely fluctuating temperatures and humidity conditions in the freezer rooms often gives rise to a collapse of the cells of the flesh, causing pocklike marks to appear upon the skin. This condition is commonly referred to as "freezer burn" and has been the cause of much trouble to storers of dressed poultry. Wrapping birds individually in moistureproof transparent sheets or asphalt papers has been shown to reduce the freezer-burn condition almost completely, provided satisfactory temperature and humidity conditions are maintained in the freezer rooms.

During recent years the quick freezing of poultry has received special consideration, several methods being employed. Lack of space prevents a detailed discussion of this most promising field in the preservation of poultry meat. For the present it appears that a range of -20 to -30°F. is the most practicable, although some work has been done which indicates that quick freezing at -12 to -15°F. tends to preserve a better color than quick freezing at lower temperatures. Quick freezing preserves the quality of poultry meat by immobilizing the water before it has a chance to escape from the cells of the flesh.

Full-drawn Poultry.—The practice of drawing poultry for quick freezing has gained considerable impetus in the last few years, the final

product being a bird ready for the oven. It is well known, of course, that the drawing of fresh-killed birds soon leads to bacterial decomposition. On the other hand, it has been demonstrated that fresh-killed poultry may be eviscerated or drawn and then subjected to quick freezing with very satisfactory results.

From the standpoint of the economics of marketing poultry it would seem that the drawing and quick-freezing of poultry is bound to expand. In the first place, the drawing of poultry in poultry packing-plants located in the country can be done at less cost than in the cities. In the

FIG. 186.—Showing the evisceration of chickens. The head and feet having been removed, each bird is then carefully eviscerated under strictly sanitary conditions. The birds are individually inspected by Federal inspectors and after being eviscerated are thoroughly washed. The pans revolve constantly, each pan being washed after each revolution. (*U. S. Egg and Poultry Mag.*)

second place, when dressed poultry is eviscerated at the packing plants there is an enormous saving in the express, freight, and truckage charges on the head, feet, and offals. In the third place, the evisceration of poultry at packing plants makes possible the saving of certain parts of the offal for fertilizer purposes in contrast to dumping it down city sewage systems, and, what is probably still more important, various endocrine glands may be salvaged which may prove to be of considerable value in the future.

The relative amount of edible meat obtainable from broilers and roasters is shown in the following table.

TABLE 56.—PER CENT OF EDIBLE FLESH IN BROILERS 10 WEEKS OF AGE AND ROASTERS 30 WEEKS OF AGE
(Maw, 1933)

Breed and class	Waste as per cent of live weight	Waste as per cent of chilled dressed weight	Per cent bones of chilled dressed weight	Edible flesh		Total edible flesh and giblets	
				Per cent of live weight	Per cent of chilled dressed weight	Per cent of live weight	Per cent of chilled dressed weight
W. Leghorn broilers:							
Males	33.83	24.62	25.78	37.14	43.30	42.62	49.69
Females	32.69	22.76	25.66	37.84	44.22	43.61	50.95
B. P. Rock broilers:							
Males	29.71	22.21	27.13	38.47	43.98	43.77	50.04
Females	30.63	21.86	25.33	39.60	45.46	45.19	51.88
R. I. Red broilers:							
Males	30.40	21.80	27.93	39.01	44.87	43.90	50.49
Females	30.98	22.05	27.37	38.18	43.82	44.10	50.60
W. Wyandotte broilers:							
Males	29.38	22.31	27.06	39.60	44.73	45.82	51.76
Females	29.86	22.87	23.88	41.59	47.16	47.71	54.11
W. Leghorn roasters	29.01	19.68	22.17	43.39	52.76	48.23	58.64
B. P. Rock roasters	24.81	16.92	22.18	47.99	55.12	51.84	59.33
R. I. Red roasters	24.68	16.98	20.72	49.08	57.09	52.79	61.40
Buff Orpington roasters	24.37	16.15	19.44	50.62	58.06	54.30	62.29

The full drawing of poultry is being practiced in a number of packing plants and bids fair to expand considerably, provided there is ready acceptance of the product on the part of the consumer. In order to ensure the ready acceptance on the part of the average consumer for full-drawn poultry it will be necessary for the retailer to provide proper storage conditions for the product.

In the preparation of quick-frozen, full-drawn poultry as carried out in several packing plants the process may be described very briefly as follows: The dressed undrawn bird is brought from the cooler, examined carefully for dressing defects, placed on a pan on an endless conveyor, eviscerated or drawn, and inspected by a federal inspector for any diseased condition that may be apparent; if passed, the head and feet are removed, and the giblets are washed and wrapped in parchment paper and stored inside the bird after it has been thoroughly washed both inside and outside. The fully drawn bird is then wrapped in cellophane, tied with a brand ribbon, and packed in white fiber boxes. Then it is quick frozen, and the retailer ultimately receives it in the quick-frozen

condition. The retailer should have a refrigerator display case for properly displaying to consumers the quick-frozen poultry products being offered for sale.

Consumer acceptance of quick-frozen, full-drawn poultry will in all probability depend upon the quality and price of the product in relation to the quality and price of other forms of dressed poultry. Undoubtedly, however, broilers and roasters "ready for the oven" will prove to have a popular appeal in many households.

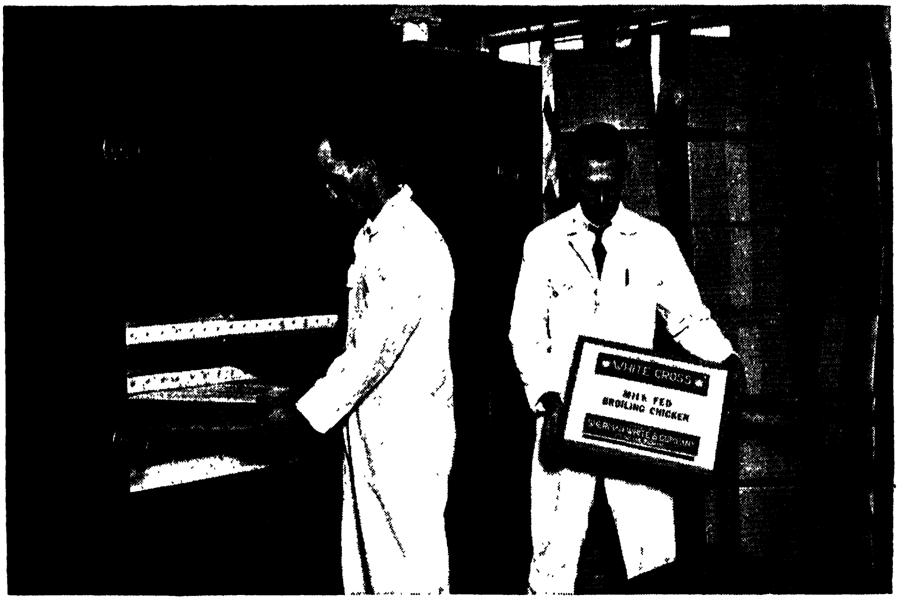

FIG. 187.—The boxes of full-drawn poultry are placed in the quick-freezing machine, shown above, and are frozen solid in about two hours at about 50 degrees below zero, in this particular case. The boxes of poultry are then removed and placed in a sharp freezer considerably below zero, where they are held until being shipped to market. Quick-freezing tends to preserve the quality of the flesh. (*Sherman White Company.*)

Canned Poultry.—The canning of poultry as a method of preservation in cans or jars has gained considerable impetus during recent years and includes the preparation of cooked whole, half, or disjointed chicken, cooked poultry meat combined with other foods, and chicken soup. In the canning of whole, half, or disjointed chicken the full-drawn bird or portion thereof is placed in a can and then steam cooked under pressure, or in some cases the bird is roasted before being canned. Some packers prepare boneless canned chicken by cooking the birds and then removing the meat, canning the latter separately or in conjunction with such foods as noodles. Many housewives also can chickens, sometimes with and sometimes without the bones. Chicken soup in various forms is canned by packers as well as by housewives.

Smoked Poultry.—The preservation of chicken meat by smoking is an ancient Chinese custom and is sometimes practiced in this country, especially by the Indians, the same methods being employed as in the smoking of hams.

Pickled Cockscomb.—Pickling the combs of cocks is a method of preservation resorted to by the French, by whom the product is considered quite a delicacy.

GRADING DRESSED POULTRY

In order to sell to best advantage, dressed poultry must be graded for size, color, finish, and conformation, the uniformity of the birds in a lot being of great importance. Dressed chickens are bought largely on the basis of their appearance. The Bureau of Agricultural Economics of the U. S. Department of Agriculture has proposed tentative specifications for U. S. standards and grades for dressed broilers, fryers, roasters, stags, cocks, capons, and fowl.

Classes of Dressed Chickens.—The definitions of the various classes of dressed chickens indicate the approximate age, size, and fleshing qualities.

Broilers.—Young chickens, approximately 8 to 12 weeks old of either sex, of marketable age but not weighing over 2½ lb., and sufficiently soft meated to be cooked tender by broiling.

Fryers.—Young chickens, approximately 14 to 20 weeks old of either sex, weighing more than 2½ lb. but not more than 3½ lb., and sufficiently soft meated to be cooked tender by frying.

Roasters.—Young chickens, approximately 5 to 9 months old, of either sex, weighing over 3½ lb., and sufficiently soft meated to be cooked tender by roasting.

Stags.—Male birds, of any weight or age under maturity, with flesh slightly darkened and toughened, and with comb and spur development showing the bird to be between roasters and cocks in age.

Cocks.—Mature male birds of any weight, with darkened and toughened flesh.

Capons.—Unsexed male birds weighing over 4 lb., usually 7 to 10 months old, and with soft and tender flesh.

Slips.—Incompletely caponized male birds, weighing over 4 lb., with comb, spur, and flesh development similar to that of stags.

Fowl.—Mature female birds of any age or weight.

Descriptive Terms of Quality Factors.—Certain descriptive terms dealing with various quality factors indicate the desirable and undesirable characteristics that determine the basis for grading the chickens belonging to different classes.

Full-fleshed.—Plump broad-breasted birds, with thighs, back, and breast well covered with fat, and all bones covered with thick layers of flesh.

Well-fleshed.—Birds with considerable sized breasts, with some fat covering over thighs and back.

Poorly fleshed.—Birds with narrow breasts and muscles, with thighs and backs showing dark from absence of fat.

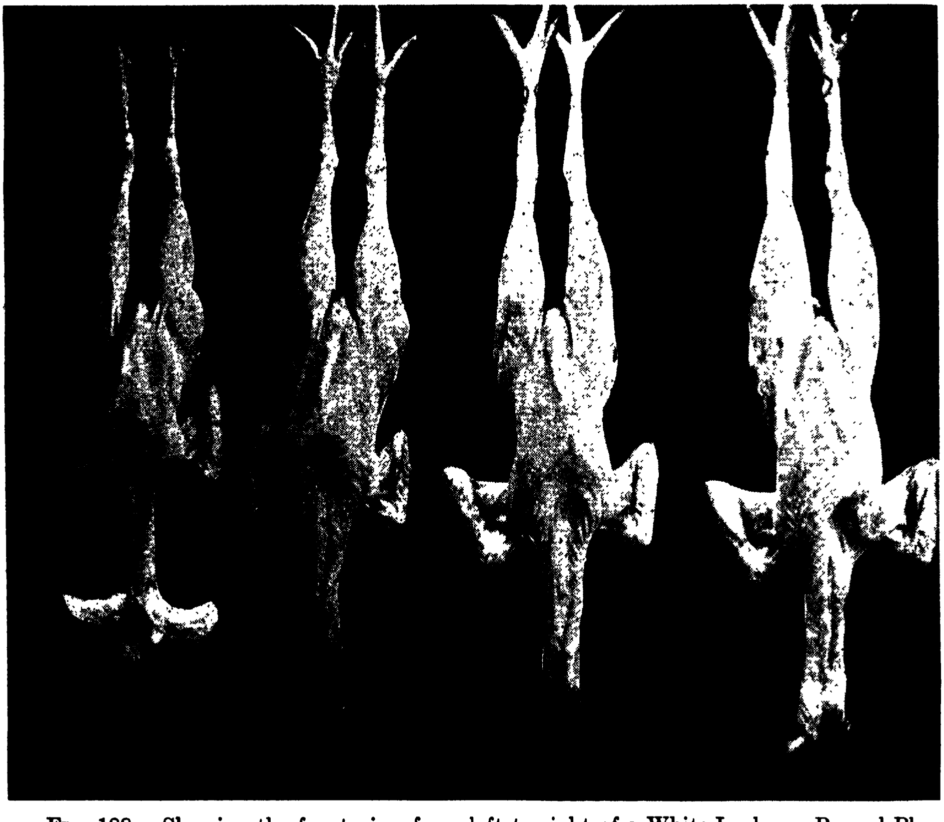

FIG. 188.—Showing the front view from left to right of a White Leghorn, Barred Plymouth Rock, Rhode Island Red, and Buff Orpington dressed carcasses of cockerels at 26 weeks of age. (*Maw*, 1933.)

Uniform pack and color.—Light-colored and yellow birds packed separately, packages to contain either all light- or all heavy-breed birds; packages and paper linings uniform in size, shape, and color.

Poorly bled.—Birds showing red pin marks on breast, thighs, or wing tips or skin reddened from blood clots.

Deformities.—Birds having hunchbacks, crooked breasts, or other serious condition unnatural to normal, healthy birds.

Slight deformities.—Birds having dented or notched breasts, crooked backs, or misshapen legs or wings.

Skin abrasions.—Reddened or bruised outer skin caused by rubbing or rough handling.

Skin bruises.—A bruise of the skin sufficient so that blood clot has formed underneath.

Flesh bruise.—A bruise extending through the skin and into the flesh of the bird.

FIG. 189.—Showing the side view from left to right of a White Leghorn, Barred Plymouth Rock, Rhode Island Red, and Buff Orpington dressed carcasses of cockerels at 26 weeks of age. (*Maw*, 1933.)

Dressing defects.—Pinfeathers scattered more or less over the entire carcass; incomplete bleeding, if shown in places other than the wing tips; a cut or tear 2 in. or more in length or more than one cut of any length; skin abrasion of more than 2 in. in diameter, or more than one abrasion of any diameter; broken leg, wing, or other bone in edible part of carcass; feed in crops; dirty feet, bodies, or vents.

Slight dressing defects.—Few scattered pinfeathers on breast or back; blood spots in wing tips; one cut or tear less than 2 in. in length; one skin abrasion less than 2 in. in diameter; one broken leg (broken below knee) or a broken wing tip.

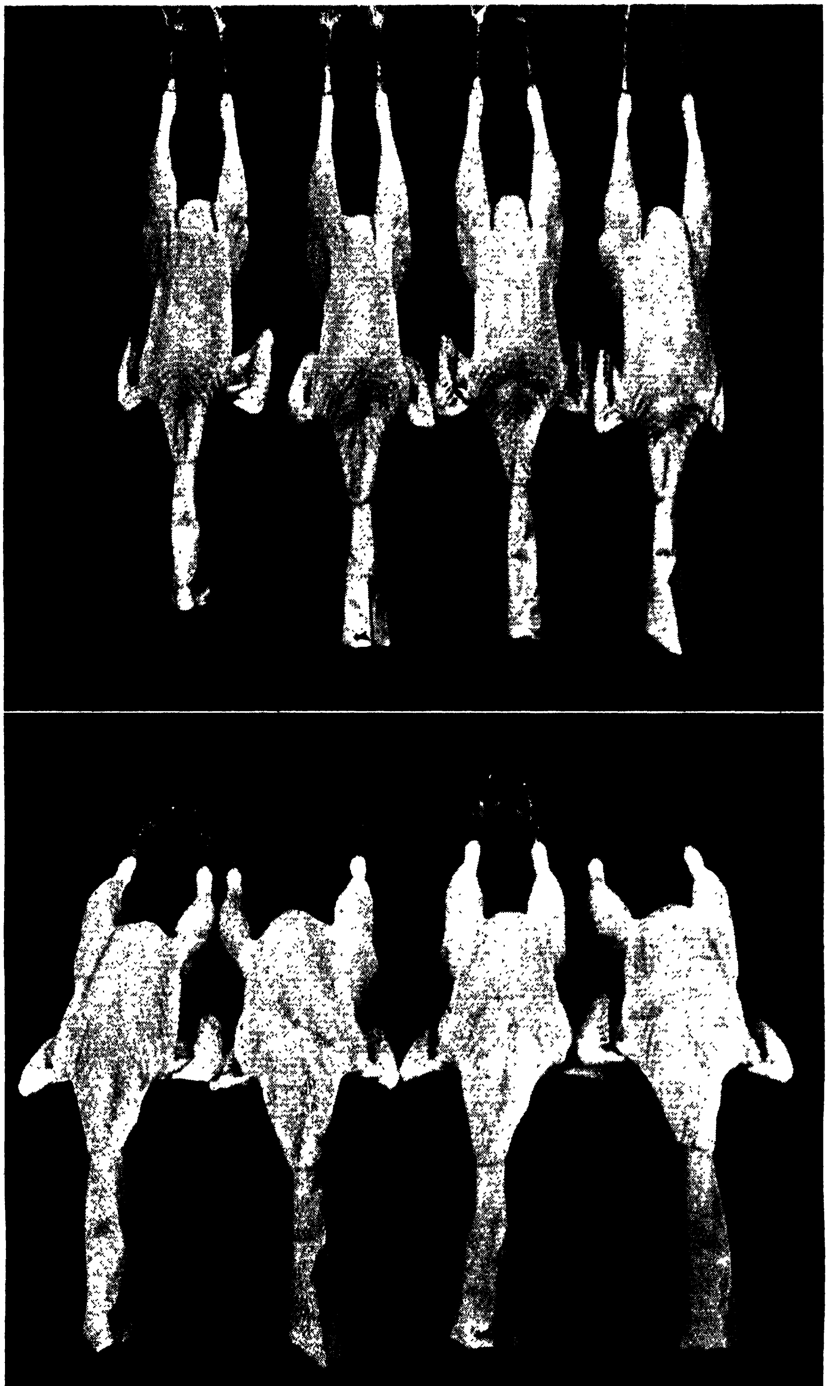

Fig. 190.—Showing remarkably well fleshed and finished roasters, being pullets produced by a cross between Cornish and Barred Plymouth Rock. (*Maw*, 1933.)

Well-dressed.—All conditions under Dressing Defects or Slight Dressing Defects excluded.

Slight comb or spur development.—Birds that have taken on the appearance of maturity; have comb growth pronounced but not fully developed; spurs developing but soft.

Edible birds.—Any birds free from disease or other condition that renders them unwholesome for human food.

Judging Dressed Poultry.—The judging of dressed chickens is good practice in order to acquaint one with the relative importance of the more important factors determining quality. The accompanying score cards are used at many institutions.

Item scored	Points	Cuts	Remarks
General appearance:			
Freedom from blemishes	10		
Freedom from deformities	5		
Method of bleeding	5		
Freedom from feathers and down	5		
Size	5		
Cleanliness	10		
Condition and quality:			
Plumpness	30		
Finish	10		
Skin texture	10		
Well bled	5		
Color	5		
Total	100		

FIG. 191.—Score card for judging individual dressed chickens.

Item scored	Points	Cuts	Remarks
General appearance:			
Freedom from blemishes	10		
Freedom from deformities	5		
Uniformity	10		
Package appearance	10		
Condition and quality:			
Plumpness	30		
Finish	10		
Skin texture	10		
Uniformity of size and color	10		
Color	5		
Total	100		

FIG. 192.—Score card for judging box-packed chickens.

Table 57.—Tentative Specifications for U. S. Standards and Grades for Dressed Broilers, Fryers, and Roasters

U. S. grades	Specifications for individual birds	Weight specifications				
		Weight range per bird		Weight per dozen birds		
		Min.	Max.	Min.	Ave.	Max.
		Broiler weights				
U. S. Special or U. S. Grade AA	Young, fine-grained, soft-meated birds with broad full-fleshed breast, the entire carcass fully covered with fat and with skin soft and glossy lying close to the flesh. Must be well bled, well dressed, free of pinfeathers, and have empty crop. No flesh or skin bruises allowed, and only slight skin abrasions or discolorations permitted, none of which shall be on the breast. No crooked breasts or other deformities allowed. A broken wing above the wing tip or a broken leg not permitted. Must be dry picked or semiscalded and dry packed	None 1 lb. 7 oz. 1 lb. 11 oz. 2 lb. 2 oz.	1 lb. 6 oz. 1 lb. 10 oz. 2 lb. 1 oz. 2 lb. 8 oz.	None 16 lb. 21 lb. 26 lb.	.... 18 lb. 23 lb. 28 lb.	16 lb. 20 lb. 25 lb. 30 lb.
		Fryer weights				
U. S. Prime or U. S. Grade A	Young, soft-meated birds, with well-fleshed breast, the entire carcass well covered with fat and with soft glossy skin. Must be well bled, well dressed and practically free of pinfeathers, and have empty crop. No flesh bruises and only very slight skin bruises, abrasions, or discolorations permitted, none of which shall be on the breast. No crooked breasts or other deformities allowed. Broken wings above the wing tips or broken legs not permitted. Birds with crops properly removed and sewn up may be included in this grade. Must be dry picked or semiscalded and dry packed	2 lb. 9 oz. 3 lb. 1 oz.	3 lb. 3 lb. 8 oz.	31 lb. 37 lb.	33½ lb. 39½ lb.	36 lb. 42 lb.
		Roaster weights				
U. S. Choice or U. S. Grade B	Young, soft-meated birds, with fairly well-fleshed breast and with carcass fairly well covered with fat. Must be fairly well bled and dressed, and may show few scattered pinfeathers over the entire carcass. Crop must be practically empty. Slight flesh or skin bruises, abrasions, or discolorations permitted, but not more than three such defects to each bird. Abrasions or tears over 3 in. in diameter not allowed except on the back or wings unless properly sewn up. Dented or slightly crooked breastbones or other slight deformities permitted. One broken wing or one broken leg in the flesh permitted if bone does not protrude through the flesh and if not showing excessive bruise or blood clot	3 lb. 9 oz. 4 lb. 4 lb. 8 oz. 5 lb. 5 lb. 8 oz.	3 lb. 15 oz. 4 lb. 7 oz. 4 lb. 15 oz. 5 lb. 7 oz. None	43 lb. 48 lb. 54 lb. 60 lb. 66 lb.	45 lb. 50½ lb. 56½ lb. 62½ lb.	47 lb. 53 lb. 59 lb. 65 lb. None
U. S. Commercial or U. S. Grade C	Young birds with poorly fleshed breast and with carcass poorly covered with fat. May show evidence of poor bleeding and have numerous pinfeathers over the entire carcass. Abrasions and discolorations permitted and hunchbacks or other deformities allowed if birds are fairly well fleshed. Birds badly bruised so as to make any appreciable part of the carcass inedible or birds emaciated or showing external evidence of disease not permitted					

TABLE 58.—TENTATIVE SPECIFICATIONS FOR U. S. STANDARDS AND GRADES FOR STAGS, COCKS, AND CAPONS

Classes	U. S. grades	Specifications for individual birds	Weight specifications				
			Weight range per bird		Weight per dozen birds		
			Min.	Max.	Min.	Ave.	Max.
Stags	U. S. Special or U. S. Grade AA	Young male birds showing considerable maturity, flesh slightly tough, spurs developing but soft, and otherwise conforming to the specifications for U. S. Special Roasters	None	3 lb.	None	....	36 lb.
	U. S. Prime or U. S. Grade A	Young male birds showing considerable maturity, flesh slightly tough, spurs developing but soft, and otherwise conforming to the specifications for U. S. Prime Roasters	3 lb. 4 lb.	3 lb. 15 oz. 4 lb. 15 oz.	36 lb. 48 lb.	41½ lb. 53½ lb.	47 lb. 59 lb.
	U. S. Choice or U. S. Grade B	Young male birds showing considerable maturity, flesh slightly tough, spurs developing but soft, and otherwise conforming to the specifications for U. S. Choice Roasters	5 lb. 6 lb.	5 lb. 15 oz. None	60 lb. 72 lb.	65½ lb. None	71 lb. None
	U. S. Commercial or U. S. Grade C	Young male birds showing considerable maturity, flesh slightly tough, spurs developing but soft, and otherwise conforming to the specifications for U. S. Commercial Roasters					
Cocks	U. S. Special or U. S. Grade AA	Mature male birds with toughened and coarse-grained flesh and otherwise conforming to the specifications for U. S. Special Roasters	None	4 lb.	None	....	48 lb.
	U. S. Prime or U. S. Grade A	Mature male birds with toughened and coarse-grained flesh and otherwise conforming to the specifications for U. S. Prime Roasters	4 lb.	4 lb. 15 oz.	48 lb.	53½ lb.	59 lb.
	U. S. Choice or U. S. Grade B	Mature male birds with toughened and coarse-grained flesh and otherwise conforming to the specifications for U. S. Choice Roasters	5 lb.	5 lb. 15 oz.	60 lb.	65½ lb.	71 lb.
	U. S. Commercial or U. S. Grade C	Mature male birds with toughened and coarse-grained flesh and otherwise conforming to the specifications for U. S. Commercial Roasters	6 lb.	None	72 lb.	....	None
Capons	U. S. Special or U. S. Grade AA	Young caponized male birds fully fatted and fine grained and otherwise conforming to the specifications for U. S. Special Roasters	None	6 lb.	None	....	72 lb.
	U. S. Prime or U. S. Grade A	Young caponized male birds well fatted and fine grained and otherwise conforming to the specifications for U. S. Prime Roasters	6 lb.	6 lb. 15 oz.	72 lb.	77½ lb.	83 lb.
	U. S. Choice or U. S. Grade B	Caponized male birds fairly well fatted, may show slight evidence of incomplete caponizing; otherwise conforming to the specifications for U. S. Choice Roasters	7 lb. 8 lb.	7 lb. 15 oz. 8 lb. 15 oz.	84 lb. 96 lb.	89½ lb. 101½ lb.	95 lb. 107 lb.
	U. S. Commercial or U. S. Grade C	Caponized male birds poorly fatted, may show evidence of incomplete caponizing; otherwise conforming to the specifications for U. S. Commercial Roasters	9 lb. 10 lb.	8 lb. 15 oz. None	108 lb. 120 lb.	113½ lb.	119 lb. None

TABLE 59.—TENTATIVE SPECIFICATIONS FOR U. S. STANDARDS AND GRADES FOR DRESSED FOWL

U. S. grades	Specifications for individual birds	Weight specifications				
		Weight range per bird		Weight per dozen birds		
		Min.	Max.	Min.	Ave.	Max.
U. S. Special or U. S. Grade AA	Mature fine-grained female birds, with broad full-fleshed breast, the entire carcass fully covered with fat and with skin soft and glossy lying close to the flesh. Must be well bled, well dressed, free of pinfeathers, and have empty crop. No flesh or skin bruises allowed, and only very slight skin abrasions or discolorations permitted, none of which shall be on the breast. No crooked breasts or other deformities allowed. A wing broken above the wing tip or a broken leg not permitted. Dislocated bones not permitted. Scaly legs or excessive abdominal fat not permitted. Must be dry picked or semiscalded and dry packed					
U. S. Prime or U. S. Grade A	Mature fine-grained female birds, with well-fleshed breast, the entire carcass well covered with fat, and with soft glossy skin. Must be well bled, well dressed, and practically free of pinfeathers, with crops empty. No flesh bruises and only very slight skin bruises, abrasions, or discolorations permitted, none of which shall be on the breast. No crooked breasts or other deformities allowed. Wings broken above the wing tips or broken legs not permitted. One dislocated wing bone permitted, if not bruised. Excessive scaly legs or excessive abdominal fat not permitted. Birds with crops properly removed and sewn up may be included in this grade. Must be dry picked or semiscalded and dry packed	None 3 lb. 3 lb. 8 oz. 4 lb. 4 lb. 8 oz.	3 lb. 3 lb. 7 oz. 3 lb. 15 oz. 4 lb. 7 oz. 4 lb. 15 oz.	None 36 lb. 42 lb. 48 lb. 54 lb.	. . . . . . 38½ lb. 44½ lb. 50½ lb. 56½ lb.	36 lb. 41 lb. 47 lb. 53 lb. 59 lb.
U. S. Choice or U. S. Grade B	Mature female birds, with fairly well-fleshed breast and with carcass fairly well covered with fat. Must be fairly well bled and dressed and may show few scattered pinfeathers over the entire carcass. Crops must be practically empty. Slight flesh or skin bruises, abrasions, or discolorations permitted, but not more than three such defects to each bird. Abrasions or tears over 3 in. in diameter not allowed, except on the back or wings, unless properly sewn up. Dented or slightly crooked breastbones or other slight deformities permitted. One broken wing or one broken leg in the flesh permitted if bone does not protrude through the flesh and if not showing excessive bruise or blood clot	5 lb. 5 lb. 8 oz.	5 lb. 7 oz. None	60 lb. 66 lb.	62½ lb.	65 lb. None
U. S. Commercial or U. S. Grade C	Mature female birds with poorly fleshed breast and with carcass poorly covered with fat. May show evidence of poor bleeding and have numerous pinfeathers over the entire carcass. Abrasions and discolorations permitted, and hunchbacks or other deformities allowed if birds are fairly well fleshed. Birds badly bruised so as to make any appreciable part of the carcass inedible or birds emaciated or showing external evidence of disease not permitted in this grade					

TABLE 60.—TENTATIVE SPECIFICATIONS FOR U. S. STANDARDS AND GRADES FOR DRESSED AND DRAWN BROILERS, FRYERS, AND ROASTERS

U. S. grades	Specifications for individual birds
U. S. Special or U. S. Grade AA	Young, fine-grained, soft-meated birds with broad full-fleshed breast, the entire carcass fully covered with fat and with skin soft and glossy lying close to the flesh. Must be well bled, well dressed, and free of pinfeathers. No flesh or skin bruises allowed, and only slight skin abrasions or discolorations permitted, none of which shall be on the breast. No crooked breasts or other deformities allowed. A broken wing above the wing tip or a broken leg not permitted. Must be dry-picked or semiscalded, dry packed, and dressed in a manner approved by the Bureau of Agricultural Economics
U. S. Prime or U. S. Grade A	Young, soft-meated birds, with well-fleshed breast, the entire carcass well covered with fat, and with soft glossy skin. Must be well bled, well dressed, and practically free of pinfeathers. No flesh bruises that cannot be removed without injury to the flesh permitted. Slight skin bruises, abrasions, or discolorations permitted, with breasts practically free of such defects. Slightly curved but no crooked breasts or other deformities allowed. One broken wing permitted if bone does not protrude through the flesh or if protruding bone has been removed provided flesh is not bruised. Must be dry picked or semiscalded, dry packed, and dressed in a manner approved by the Bureau of Agricultural Economics
U. S. Choice or U. S. Grade B	Young, soft-meated birds, with fairly well-fleshed breast, and with carcass fairly well covered with fat. Must be fairly well bled and dressed and may show few scattered pinfeathers over the entire carcass. Slight flesh or skin bruises, abrasions, or discolorations permitted. Abrasions or tears over 3 in. in diameter not allowed except on the back or wings unless properly sewn up. Dented or slightly crooked breastbones or other slight deformities permitted. Broken wings or one broken leg in the flesh permitted. Must be dry picked or semiscalded, dry packed, and dressed in a manner approved by the Bureau of Agricultural Economics
U. S. Commercial or U. S. Grade C	Young birds with poorly fleshed breast and with carcass poorly covered with fat. May show evidence of poor bleeding and have numerous pinfeathers over the entire carcass. Abrasions and discolorations permitted, and hunchbacks or other deformities allowed if birds are fairly well fleshed. Birds badly bruised so as to make any appreciable part of the carcass inedible or birds emaciated or showing external evidence of disease not permitted. Must be dry picked or semiscaled, dry packed, and dressed in a manner approved by the Bureau of Agricultural Economics

Most exhibits of dressed poultry are comprised of birds packed in boxes, the uniformity of the birds in a box being a very important matter as well as the style of packing the birds in a box.

Cutting for defects in the various sections should be determined by the total number of points for each section and by the seriousness of each defect.

U. S. Grades of Chickens.—The following tentative U. S. grades of chickens have been established:

U. S. Special or U. S. Grade AA.—Commercially perfect specimens of any class.

U. S. Prime or U. S. Grade A.—The second highest grade.

U. S. Choice or U. S. Grade B.—The third highest grade.

U. S. Commercial or U. S. Grade C.—The lowest grade of edible chickens.

PACKING DRESSED POULTRY

Various styles and sizes of baskets, barrels, and boxes are used for shipping dressed chickens to market. Boxes include cardboard boxes for parcel-post shipping and wooden ones for freight and express shipments. Baskets are used for parcel-post shipments; and barrels, for freight and express shipments of dressed poultry.

STANDARD SIZES—SIX BIRDS PER BOX—EACH BIRD WRAPPED IN CELLOPHANE

Class	Weight equivalents for 12 birds not drawn, lb.	Length, width, and depth, net inside, inches
Broilers	17–20—Broilers	12¾ × 9 × 3¼
Broilers	21–24—Broilers	13½ × 9¾ × 3½
Broilers	25–30—Broilers	14¼ × 10 × 4
Fryers	31–36—Fryers	15 × 10¾ × 4¼
Fryers	37–42—Fryers	16 × 11¼ × 4½
Roasters	43–47—Roasters	17 × 11¾ × 4¾
Roasters	48–54—Roasters	17½ × 12¼ × 5
Roasters	55–59—Roasters	18 × 12¾ × 5
Roasters	60–65—Roasters	19 × 13 × 5¼
Roasters	66–71—Roasters	19½ × 13¼ × 5½
Roasters	72 and up	20 × 13½ × 5¾
Fowl	Up to 29—Fowl	None drawn
Fowl	30–35—Fowl	15½ × 10 × 4
Fowl	36–42—Fowl	16 × 10½ × 4½
Fowl	43–47—Fowl	17 × 11 × 4¾
Fowl	48–54—Fowl	17½ × 11¼ × 5
Fowl	55–59—Fowl	18½ × 11¾ × 5¼
Fowl	60–65—Fowl	19 × 12¼ × 5½
Fowl	66–71—Fowl	None drawn
Fowl	72 and up—Fowl	None drawn

Baskets.—Splint baskets are sometimes used for shipping one or more dressed chickens by parcel post. Drop handles should be used, and corrugated paper board should line the inside of the basket.

Barrels.—Barrels are sometimes employed for shipping large numbers of dressed chickens, usually of the lower grades, either by express or by freight. The barrel method of packing is being rapidly supplanted by the box method.

Paper Boxes.—Corrugated paper-board boxes are commonly used in shipping dressed chickens by parcel post. Each box should be of the proper size for the size of chicken to be shipped. Chickens are usually shipped singly or in pairs and each bird should be carefully wrapped in parchment paper, after the head and feet have been separately wrapped. The chickens should be cooled thoroughly before being wrapped and packed for shipment. Strict care should be observed that no odors of any kind are on the packing materials because poultry absorbs odors readily. The boxes should be rigid enough to stand rather rough handling. All parcel-post shipments should be marked "Poultry—Perishable." Paper or fiber boxes are being used successfully for shipping quick-frozen, full-drawn chickens.

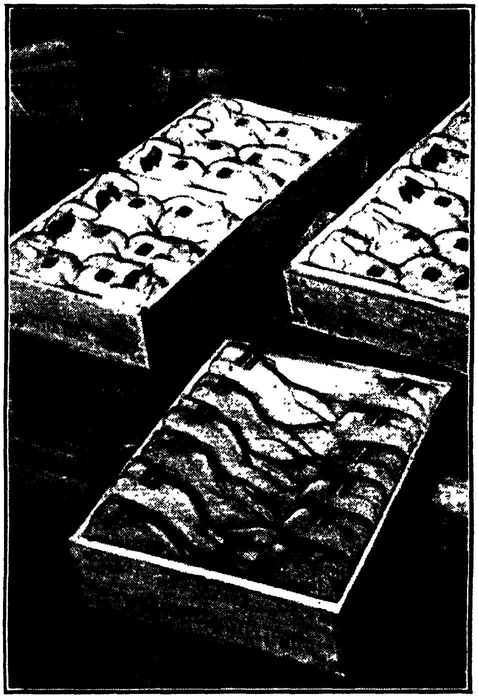

Fig. 193.—Dressed fowl and broilers packed in boxes. (*U. S. Egg and Poultry Mag.*)

The sizes of corrugated boxes are recommended by the National Container Association for packing full-drawn poultry as shown in the table on p. 464.

Wood Boxes.—Most of the dressed chickens sold annually are packed in wooden boxes, 6 or 12 to a box. The size of the box is determined by the size of the chicken to be packed. Its shape is determined by the style of the pack, whether in a single layer of two rows or in two layers, the single layer being more desirable.

The method of packing generally used is to place a single layer of chickens in the box with breasts up, the fleshing being shown to best advantage. The most compact method of packing is the double-layer, side-pack method, but it has the objection that when the box is opened the lower layer of birds cannot be seen. The single-layer side pack method is used to only a limited extent.

The heads of the chickens are wrapped separately, and frequently birds of superior quality are wrapped individually in waxed or water-finished fiber paper. The boxes should be lined with parchment or wax-coated paper. Some packers use a waterproof, asphalt-centered paper lining, which tends to prevent desiccation during storage. The practice of labeling each bird with an attractive label is increasing, especially for the better grades of chickens. Shredded wax paper, or shredded colored celophane is sometimes used to fill up the spaces between the birds, a practice that adds to the attractiveness of the pack.

The boxes should be properly stenciled, stating the kind and number of chickens; the grade; the weight class; and the gross, tare, and net weights. Frequently much of this information is given in the form of a code.

METHODS OF MARKETING DRESSED POULTRY

The methods of marketing dressed poultry are much the same as those of marketing live poultry and vary all the way from the direct-to-consumer to a very complicated method involving the reselling of the birds several times before they reach the consumer. Dressed chickens are shipped by express, in refrigerated cars and trucks, and may be handled by a receiver or commission merchant, a broker, a jobber, and a retailer.

Shipping by Express.—Sometimes dressed chickens are shipped in small lots by express, particularly when the producer sells directly to the consumer.

Shipping in Refrigerator Cars.—Standardized refrigerator cars have been constructed in which refrigeration is accomplished by means of ice placed in ice bunkers at the end of each car and by means of a mechanical-compression system of refrigeration.

Refrigeration with ice involves using broken or crushed ice in the bunkers which are so designed that the cold air from the melting ice sinks and passes out into the car, forcing the warmer air in the car upward and toward the ice bunkers where it is again cooled. From 5 to 12 per cent salt is mixed with the ice to keep the temperature of the car at about 15 to 20°F. In warm weather the refrigerator car should be chilled before it is loaded, and ice and salt should be added every 2 or 3 days. For chilling before loading, a portable precooling apparatus connected with brine pipes or direct ammonia lines has been found quite satisfactory.

In the mechanical-compression system of refrigeration, power is supplied from the axle when the car is in motion, brine tanks being a part of the equipment. When the refrigerator car is standing still, electric current must be obtained from an available source in order to drive the motor. Mechanical refrigeration is also accomplished in some cars by

using Diesel engines which run continuously, the refrigeration system coming into action as the temperature may require.

Refrigerator cars should be kept clean and sanitary at all times, and the doors should fit tightly.

Shipping in Refrigerator Trucks.—The principal of refrigeration in trucks is the same as in mechanically refrigerated cars.

Terminal-marketing Methods.—The distribution of dressed poultry after it arrives at a large terminal market is not nearly so complicated as that of live poultry. Relatively small quantities of dressed chickens are shipped direct from producer to consumer. Considerable quantities are shipped by producers to wholesale receivers or commission merchants, who may sell direct to retailers; or the shipment may be handled by a broker or a jobber. The wholesale receiver buys and sells the shipment, whereas the commission merchant operates on a commission basis. Brokers assist shippers and buyers in finding a market for the product. The jobber supplies the retailer's needs. The retailer sells to the consumer and is responsible to a large extent for the quality and appearance of dressed chickens as they are finally delivered to the consumer. The temperature of display containers should be maintained below 40°F., but for quick-frozen poultry much lower temperatures should be maintained.

FACTORS AFFECTING POULTRY PRICES

As in the case of eggs, so in the case of poultry, the law of supply and demand is effective to a considerable extent in determining prices, although the relative price of other meats sometimes plays a part. The quality of poultry is also an important factor. The great bulk of the chickens is marketed each year in the fall and winter months, especially just prior to Thanksgiving and Christmas. Broilers, however, reach the market every month in the year, the heaviest shipments being made from April to August. Prices of fowl remain fairly constant throughout the year, whereas prices of broilers fluctuate widely, the prices from February to June, inclusive, usually being higher than at other times. At the same time, there has been a tendency during recent years for broiler prices to remain more steady throughout the year than was the case a decade ago.

In an economic survey of the live-poultry industry in New York City conducted by the U. S. Department of Agriculture, it was found that there is a tendency for the relationship between dressed- and live-poultry prices to remain at approximately the same levels throughout the year. It was further found that prices paid to producers are closely associated with wholesale prices and prices paid by consumers.

Since New York City is the largest live-poultry market in the country, it is interesting to observe the manner in which daily live-poultry quota-

tions are established in this market. A representative of the price-quoting agency makes contacts with buyers and sellers at the freight terminal of the New York Central Railroad. Offers to sell and offers to buy various classes and grades of live poultry are considered for about 30 min., as the result of which the daily quotation is usually established. One of the inherent difficulties of this system of quoting prices is that

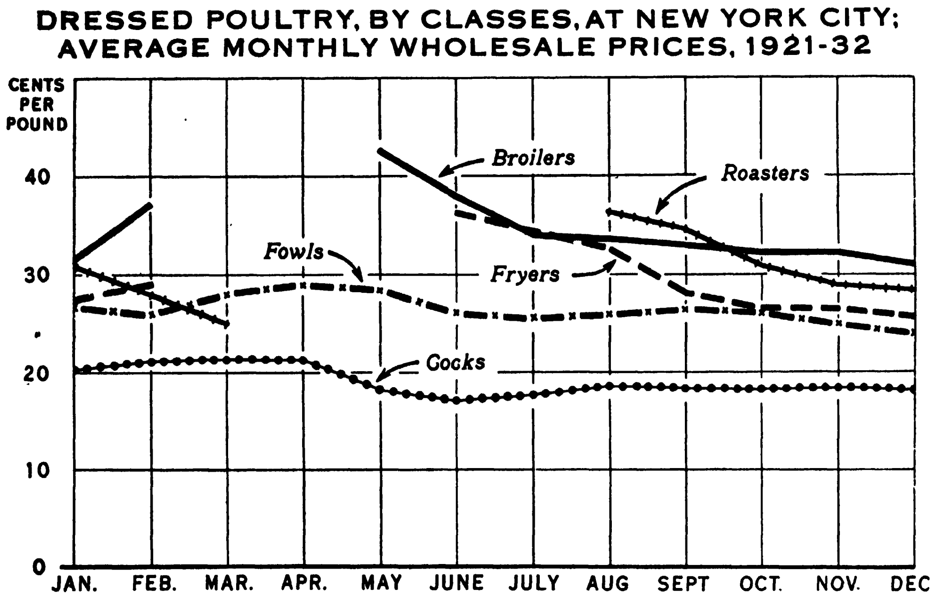

FIG. 194.—Poultry is marketed in largest volume toward the close of the year. The effect of this increase in marketing is shown in the seasonal trend of prices. In May, broilers are scarce and prices are high, but prices fall rapidly as the season advances and the supply increases. The same is true of the other two classes of young poultry, fryers and roasters. Roasters are the heaviest of the young chickens, and those which are not sold as fryers or broilers eventually become either roasters or later cocks. After the first of the year the volume of marketings declines and prices rise. Roasters, however, become "staggy" as they advance in age, and prices decline after the first of the year approaching the level of prices for cocks. Fowl are sold in considerable volume all the year, but the season of fowl marketing is low during the spring months when egg production is highest, and fowl prices are highest during those months. Culling of laying flocks increases fowl marketings and depresses prices in June and July. At the close of the year pullets are substituted for fowl in the laying flocks, fowl marketings are again heavy, and prices are again depressed.

few transactions are reported which serve as a basis for price quotations. Nevertheless, the prices paid to producers whose live poultry is shipped from surplus-producing areas to the New York City market is closely associated with the prices paid at wholesale and by consumers in New York City.

POULTRY-CONSUMPTION PROBLEMS

Many factors affect the consumption of poultry meat, some of the most important being the family income, the actual price, the price in

relation to other meats, preference for poultry meat because of religious beliefs, the quality, including flavor, and the ease with which poultry as purchased can be prepared for consumption. Estimates of the average per capita consumption of poultry meat in the United States indicate that during the past decade about 20 lb. were consumed annually. It seems quite certain, however, that more poultry mean is consumed per person in the country than in the cities.

From a survey of the consumption of poultry in New York City conducted by the U. S. Department of Agriculture it was found that the

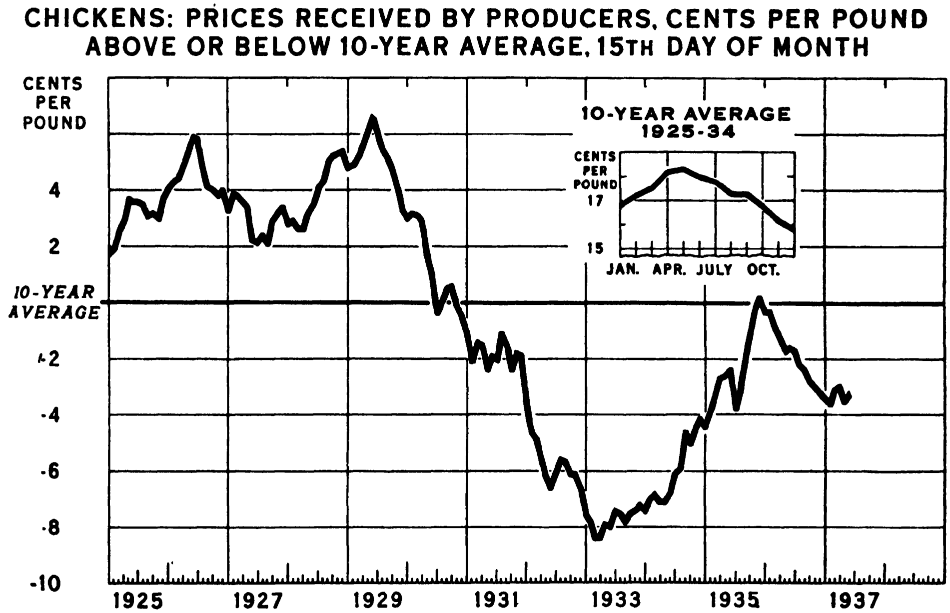

FIG. 195.—Prices received by producers of chickens declined very rapidly after 1929, but also started to rise early in 1933. In 1934 the hatch was small, poultry supplies were further reduced by sale at light weights, due to drought, and prices advanced rapidly. In 1936 the hatch was very large and again there was heavy sales of poultry under pressure of drought, but in this instance the large supplies available for sale, together with a very large volume of turkeys, were sufficient to drive chicken prices to lower levels. The large stocks of dressed poultry in cold storage were sufficient to continue the price-depressing effect of larger supplies even after the peak of marketing had passed. (*U. S. Dept. Agr.*)

family income is an important factor in determining whether or not any poultry meat is purchased and, if so, the quantity purchased. Only about one-third of the families having an average weekly income of $10 purchased any poultry; about one-half of the families having an average weekly income of $20 purchased any poultry; about two-thirds of the families having an average weekly income of $40 purchased any poultry; among families receiving more than $40 per week there was a very slight increase in the proportion of families that purchased poultry as the family income was increased. Probably the greatest relative increase in the

consumption of poultry in cities would result from an increase in the average weekly income of families receiving less than $40 per week.

It was also found that as the average weekly family income was increased, more pounds of poultry per family were purchased. Although the average size of the family was found to have little influence on the proportion of families purchasing poultry, more pounds of poultry were purchased as the size of the family was greater, on the average. Variations in price were found to be much more effective in influencing the proportion of families that purchased poultry than in the amount of poultry bought by families that purchased. In other words, those families which made a practice of purchasing poultry purchased about the

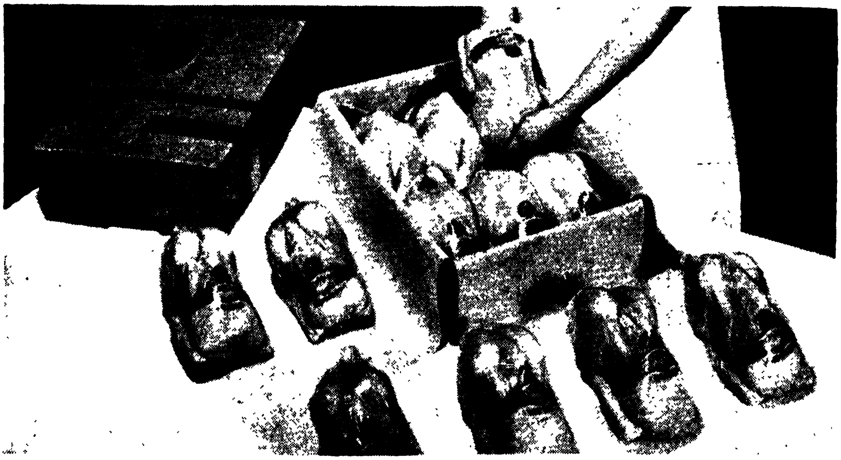

FIG. 196.—Quick-frozen, full-drawn chickens are meeting with ready acceptance on the part of consumers. (*Fairmont Creamery Co.*)

same amount from time to time, to a certain extent, regardless of price, family income, or size of family.

The consumption of poultry meat is influenced to a considerable extent, especially in certain cities, by the number of people of the Jewish faith, a higher proportion of whom buy poultry than is the case among other races. In the New York City survey it was found that 95 per cent of Jewish purchasers of poultry bought live poultry, whereas 85 per cent of the non-Jewish purchasers bought dressed poultry. About 72 per cent of the Jewish purchases of poultry was made on Thursday and Friday, whereas about 67 per cent of the purchases made by other nationalities was on Saturday. Chicken is a very popular food among Jews on their many holidays, a list of which is given in Table 61.

The quality of poultry meat is an important factor affecting its consumption, poorly finished scrawny birds that lack flavor tending to decrease consumption. Well finished, plump, fresh-killed poultry is always in popular demand. It has been pointed out in the chapter on

TABLE 61.—DATES OF JEWISH HOLIDAYS FROM 1939 TO 1943, INCLUSIVE
(Swift and Company, 1937)

Name of holiday	1939	1940	1941	1942	1943
Purim	Mar. 5	Feb. 23	Mar. 13	Mar. 3	Feb. 19
Passover	Apr. 4 to Apr. 11	Apr. 23 to Apr. 30	Apr. 12 to Apr. 19	Apr. 2 to Apr. 9	Apr. 20 to Apr. 27
Feast of Weeks	May 24, 25	June 12, 13	June 1, 2	May 22, 23	June 9, 10
Tishah b'ab	July 25	Aug. 13	Aug. 2	July 23	Aug. 10
Rosh Hashana	Sept. 14, 15	Oct. 3, 4	Sept. 22, 23	Sept. 12, 13	Sept. 30 to Oct. 1
Yom Kippur	Sept. 23	Oct. 12	Oct. 1	Sept. 21	Oct. 9
Feast of Tabernacles	Sept. 28 to Oct. 4	Oct. 17 to Oct. 23	Oct. 6 to Oct. 12	Sept. 26 to Oct. 2	Oct. 14 to Oct. 20
Shmini Azereth	Oct. 5	Oct. 24	Oct. 13	Oct. 3	Oct. 21
Simhath Torah	Oct. 6	Oct. 25	Oct. 14	Oct. 4	Oct. 22
Hanukkah	Dec. 7 to Dec. 14	Dec. 25 to Jan. 1	Dec. 15 to Dec. 22	Dec. 4 to Dec. 11	Dec. 22 to Dec. 29

feeding practices that the kind of diet affects the fleshing and the palatability of the flesh. In cooking tests conducted at Macdonald College it

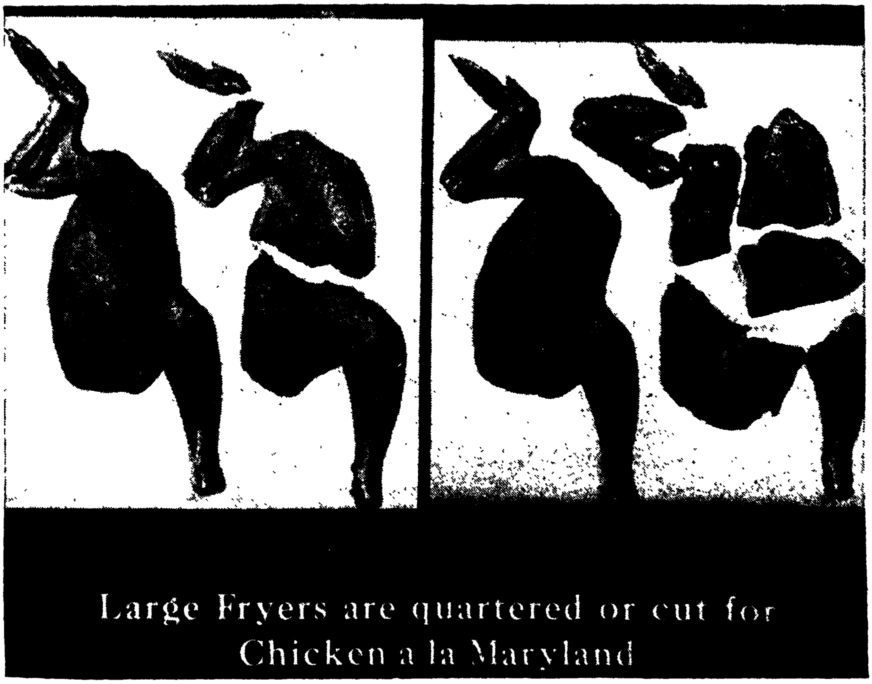

FIG. 197.—Many housewives prefer to purchase fresh-killed poultry cut-up ready for frying, particularly "a la Maryland." (*U. S. Egg and Poultry Mag.*)

was found that the degree of fleshing, as between well-fleshed, reasonably well fleshed, and fairly well fleshed birds, bore a direct relation to the relative amount of edible meat and fat in the carcass. The greater

evaporated moisture loss in cooking the poorer grades resulted in a drier meat.

The quick-freezing of full-drawn poultry bids fair to lead to an increase in the per capita consumption of poultry meat, because of its being "ready for the oven" and because quick freezing tends to conserve the quality and flavor of the poultry at killing time. The ease with which it can be prepared for consumption is an important factor in influencing the modern housewife to purchase poultry.

MARKETING BY-PRODUCTS

The by-products of the chicken industry include principally certain endocrine glands, feathers, and manure, all of which have considerable value, and dead birds and offal from poultry packing and canning plants. The principal source of the commercial feather supply is the poultry packing plant, since the number of chickens killed at home is relatively so few that the amount of feathers obtainable is very limited. Chicken manure produced at home is usually applied directly to the land, while that collected in poultry packing plants is sometimes specially prepared as fertilizer. In packing plants, dead birds and offal and blood-soiled feathers are often added to the manure in the preparation of fertilizer. Chicken blood from packing houses is sometimes mixed with hog feed.

Endocrine Glands.—The practice has been developed recently in some of the dressing and packing plants of salvaging some of the endocrine glands, which are the ductless glands of the body which produce certain hormones. The physiological effects produced by some of these hormones have been discussed in the earlier chapters of this book. The endocrine glands include the pituitary, thyroid, parathyroid, adrenal, gonads, and pancreas, and some of them are being removed and prepared for biological use. It is possible that they may have distinct commercial value.

Feathers.—Although feathers are a by-product of the chicken industry, they have extensive uses, especially in the manufacture of millinery specialties and in the making of pillows, cushions, mattresses, dusters, artificial flowers, and for other purposes. The various kinds of feathers, such as wing and tail, body, white, colored, dry plucked, scalded, clean, and dirty, should be kept separate. Feathers are stored in large, well-ventilated rooms where they are stirred daily until thoroughly dried or they are dried by a specially constructed drying machine when the chickens are dry plucked, the feathers being collected from the floor or from boxes by means of suction pipes. Where the chickens are slack scalded, the feathers are run through a presser to press out much of the water and are then transformed to the drying machine.

White feathers are worth much more than colored ones, but all have a market value.

Manure.—Chicken manure is of considerable value as a fertilizer because it contains nitrogen, potash, and phosphoric acid. It is richer in plant food constituents than that of other farm animals. It has been estimated that 100 hens averaging 5 lb. each in weight will produce in one year approximately 4,250 lb. of manure containing 43 lb. of nitrogen, 16 lb. of potash, and 34 lb. of phosphoric acid.

The average plant-food content of chicken manure has been given as follows: nitrogen, 1.44 per cent; potash, 0.39 per cent; phosphoric acid, 0.99 per cent. When chicken manure is collected in considerable quantities it should be stored in a covered shed or box and is better if mixed with some absorbent material such as straw, peat, or loam. Adding acid phosphate to the manure tends to reduce the loss of nitrogen, because the acid phosphate combines with the ammonia as it is formed and produces nonvolatile salt of ammonia. For this reason acid phosphate is a good substance to sprinkle on droppings boards.

Poultry manure, because of the high availability of its nitrogenous content, may be used in place of nitrate of soda around apple trees or in place of either nitrate of soda or mixed fertilizers for top-dressing hay land. It is also suitable for general farm crops and market-garden crops. Single applications should not exceed 2 to 3 tons per acre, both because of danger of burning the crop or giving it an overration of nitrogen and on account of probability of heavy loss by leaching.

Dead Birds and Offal.—Dead birds accumulating in poultry packing plants are utilized in making fertilizer and soap. The practice is increasing of "drawing" poultry in the more important areas of production before shipping the finished product to the more important centers of consumption. This means that larger quantities of offal are collected in the Middle West than formerly, with the result that practical means are being developed whereby the offal may be converted into fertilizer most economically. The same thing is being done at many of the poultry-canning plants located in different parts of the country.

Eggshells, Infertile Eggs, and Dead Embryos.—These are by-products of the commercial hatchery business and, taken in their aggregate for the country as a whole, reach enormous proportions, inasmuch as there are probably more than 12,000 hatcheries in operation annually. Up to the present these by-products have been used as fertilizer and for hog-feeding purposes as well as in tanning. When properly prepared, however, they have good feeding value for poultry.

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CHAPTER XIII

THE ECONOMICS OF PRODUCTION AND MARKETING

The development of the poultry industry to its present state has been brought about largely by the demand for poultry products in the human diet and by the relative economy in the production of these products in comparison with some of the other animal food products. Eggs are supplied to consumers in the shell and in the frozen and dried state and are used in the diet in a great variety of ways, in cooking, baking, and confectionary making, and occupy a unique place in the human dietary in providing protein as well as certain minerals and vitamins. Poultry meat is supplied by different classes of chickens and is served in many different forms, the white meat providing a change from the red meats supplied by the larger classes of domestic livestock. The dietetic value of eggs and poultry meat has been well established and will undoubtedly continue to serve an important role in providing the population with a fully adequate diet.

As compared with the larger classes of domestic livestock used for the production of food of animal origin, the chicken is a smaller economic unit capable of more rapid improvement. This is borne out by the remarkable development of the poultry industry in the United States during the last 50 years. During this period the increase in the poultry population practically kept pace with that in the human population, but the per capita production of eggs has increased by almost two and one-half times. This remarkable increase in egg production is accounted for through the adoption of improved methods of breeding, culling to improve the efficiency of the laying flocks, the feeding of better balanced diets, and better methods in the management of the laying flocks.

It is interesting to observe that the poultry industry of the United States has grown to such proportions that this country leads all the other nations from the standpoint of poultry population and number of eggs produced annually.

By the time of the first settlements in the United Stated edible birds, domestic and wild, were largely classed together as "fowl." The plentifulness of wild fowl in the colonies undoubtedly detracted from the importance of domestic birds. Eggs were appreciated but were almost entirely a warm-weather product. There was slight commercial aspect to poultry keeping previous to 1825, most frequent mention of poultry

products in the newspapers before that time being the feathers for beds and pillows. Between then and 1860 cheap grain in the inland districts and improved transportation encouraged egg production in the Ohio Valley.

In 1839 there were 16 states with poultry valued at over $250,000 each. New York, with poultry valued at $1,153,413, Virginia, and Pennsylvania had the largest numbers, although Ohio, Tennessee, and Kentucky were only slightly lower in poultry value than Pennsylvania. Wisconsin and Iowa, the westernmost states listed, had about $16,000 worth each.

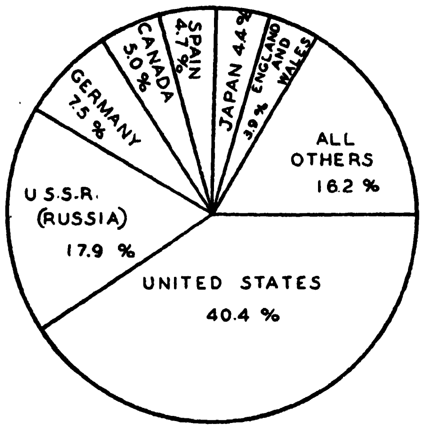

FIG. 198.—Of the estimated number of over one billion laying hens in 23 countries in 1929, the United States ranked first with over 40 per cent of the total. The poultry population of China is not included in the estimate because of lack of data. (*Wisconsin Dept. Agr.*)

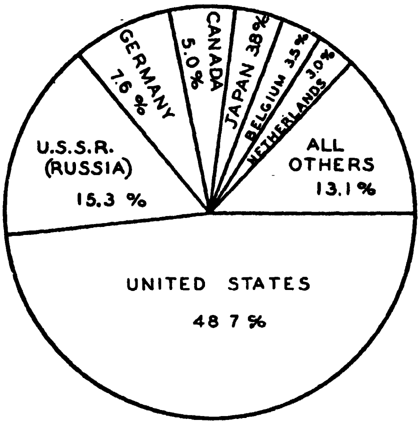

FIG. 199.—Of the estimated 66 billions of eggs produced during 1930 in 19 major countries, except China, the United States is credited with almost one-half of the total production. (*Wisconsin Dept. Agr.*)

As the commercial aspect became dominant, poultry keepers saw the importance of increasing production per hen and in developing more economical methods of raising chickens. By 1840 or 1845 increasing attention was given to breeding, feeding, and other problems of management and to the introduction of new breeds. Asiatic fowls were first imported in important quantities shortly before 1850. Their popularity led to the first "hen fever" in the fifties, after which a rapid succession of breeds claimed attention. By 1849, when the New England poultry breeders and fanciers held their first poultry show, Cochins, Shanghais, and Plymouth Rocks had become well known. In 1847 two patents were issued on "methods of incubation," though it was 40 years later that the first practicable incubator was invented.

The egg market offered the main stimulus to improvement in the early history of the poultry industry. Not only were eggs more of a luxury than poultry in a land of abundant meat, but they withstood holding and

transportation as meat and fowls could not. Consequently, many eggs were produced, and prices ranged comparatively high. In 1863 egg shipments were reaching New York City from Ohio, Indiana, Illinois, and Minnesota. During 1866 the city received 150,000 barrels of eggs, averaging over 70 doz. to the barrel.

Until the development of cold storage, marketing was limited by lack of means for preservation. Eggs were often preserved by immersion in limewater to seal the porous shell and, by 1870, were sometimes stored in fruit- or icehouses. The last method displaced the others in the eighties and gradually became our modern cold storage, which accelerated the increase in poultry during the eighties and nineties and has continued to lessen the seasonal variation in poultry and egg prices. In connection with the more costly storage and transportation coming into use, the displacement of the barrel by the 30-doz.-egg case about 1880 was a considerable economy. The production of dressed poultry as well as of eggs was greatly stimulated by the demonstrated practicability of refrigeration for both transportation and storage.

During recent years five cities, New York, Chicago, Philadelphia, Boston, and San Francisco, have required annually approximately over 500,000,000 doz. eggs and about 350,000,000 lb. of dressed poultry. The average daily requirements of the district served from New York City are now over 500,000 doz. eggs, about 450,000 lb. of dressed poultry, and about 35 carloads of live poultry. Over 2,500,000,000 doz. eggs are now produced annually in the United States.

Poultry raising occupies an important place in a well-balanced agriculture. According to the census of 1935, poultry was raised on about 86 per cent of the farms in the United States, and on many farms poultry products were reported to be one of the best paying crops. There were over 5,833,000 farm- and commercial-poultry raisers in 1935. Poultry utilize enormous quantities of waste products, including grains and other feed, the value of which could hardly be utilized otherwise in as efficient a manner as in the production of eggs and poultry meat. Poultry are foragers, and secure a part of their living from grass and other green feed and insects. The raising of poultry utilizes labor and is a source of cash returns for practically every month of the year. Furthermore, eggs and poultry meat contribute an essential variety to the diet of the farm home table and, in addition, dispense with the necessity of providing for the table much meat food that would otherwise have to be purchased.

The relative importance of poultry raising as a branch of agriculture in the United States is revealed by the data given in Table 62.

The data in this table show that among the various agricultural commodities in 1935, poultry—including chickens, turkeys, ducks, and geese—and eggs ranked third in importance, being exceeded only by dairy prod-

ucts and cattle and calves. Moreover, inasmuch as a considerable number of cattle and calves are contributed by the dairy industry as distinguished from the beef-cattle industry, it would appear that in 1935 the poultry industry was the second most important branch of agriculture from the standpoint of gross income.

A factor of considerable importance which is often overlooked is that the cash income of poultry raised and eggs produced each year in relation to the farm value and gross income of these products is higher than in the

TABLE 62.—GROSS INCOME FROM FARM PRODUCTION BY GROUPS OF COMMODITIES, 1929, 1932 TO 1935
(U. S. Department of Agriculture, 1936)
(In millions of dollars)

Source of income	1929	1932	1933	1934	1935
Crops:					
Grains	1,297	452	601	546	745
Fruit and nuts	707	324	412	451	507
Vegetables	1,130	611	754	642	772
Sugar crops	83	69	79	62	76
Cotton and cottonseed	1,389	464	688	707	698
Tobacco	286	108	179	225	237
Other crops	542	267	319	344	390
Total crops	5,434	2,295	3,032	2,977	3,425
Livestock and livestock products:					
Cattle and calves	1,111	499	476	713	920
Hogs	1,531	548	617	638	869
Sheep and wool	262	106	152	184	195
Poultry and eggs	1,241	609	561	664	884
Dairy products	2,323	1,260	1,263	1,418	1,681
Others	39	20	27	27	36
Total livestock	6,507	3,042	3,096	3,704	4,585
Total crops and livestock	11,941	5,337	6,128	6,681	8,010

case of many other agricultural commodities. The average producer attaches considerable importance to the weekly or monthly cash receipts obtained from the poultry enterprise in paying the grocer's and doctor's bills, buying schoolbooks and clothing, and paying taxes. The poultry industry is also unique among the various animal and plant industries in that it is well adapted for the development of 4-H Club and Future Farmers of America projects which often lead to the development of improved practices in agriculture as a whole as well as the poultry enterprise.

From the standpoint of the annual farm value, the number of eggs produced is of considerably greater importance than the number of

chickens raised. In 1924 and 1935 the farm value of eggs produced amounted to approximately 58 and 65 per cent, respectively, of the farm value of chickens raised and eggs produced. The relatively greater importance of egg production probably explains why the reports of crop correspondents of the Bureau of Agricultural Economics of the U. S. Department of Agriculture observed that in 1930 approximately 37 per cent of the laying stocks of the country were Leghorns, 17 per cent Plymouth Rocks, and 17 per cent Rhode Island Reds and New Hampshires. In several states, however, more than half of the laying stocks were comprised of Plymouth Rocks, Rhode Island Reds, and New Hampshires.

In round numbers the laying flocks of the United States comprise approximately 400,000,000 hens; approximately 650,000,000 chickens are raised, and approximately 2,500,000,000 dozen eggs are produced annually. These numbers change somewhat from year to year, depending upon prices; weather conditions, including droughts and the severity of the winter season; and other factors. It is pertinent to observe at this time, however, that the census figures are probably at best very rough approximations, and it is highly possible that the annual production of eggs is greater than that reported by the census enumerators.

In Tables 63 and 64 data are given on the estimated farm value and cash income from chickens raised and eggs produced in 1935. Farm value relates to the evaluation of the eggs produced and chickens raised, irrespective of the use to which they were put. Cash income relates to the value of the eggs and chickens that were sold.

The United States can be divided into fairly distinct sections according to their geographical location and the character of the industry.

The first section comprises principally the states lying in the Mississippi Valley, including Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Nebraska, Kansas, Missouri, Kentucky, and Tennessee. This extensive grain- and stock-raising section produces an enormous quantity of eggs and poultry meat, the feed cost of egg production being lower than elsewhere in this country. There are comparatively few specialized or commercial poultry farms; but the total poultry production is far in excess of the requirements for home consumption, so that a large proportion is marketed in the eastern consuming centers.

The second section comprises the northeastern states, including New England, New York, Pennsylvania, New Jersey, Maryland, and Delaware. In this section the poultry industry is one of major importance in agriculture, and many large and specialized poultry farms have been developed. At the same time, because of the very high proportion of the consuming population living in this section, the supply of poultry products from within the section is wholly inadequate to meet the demand, and

TABLE 63.—ESTIMATED FARM VALUE, GROSS INCOME, AND CASH INCOME FROM CHICKENS RAISED IN 1935
(U. S. Department of Agriculture)

State	Raised, thousands of chickens	Home consumption, thousands of chickens	Sold, thousands of chickens	Farm price per head, cents	Farm value, thousands of dollars	Cash income, thousands of dollars
Maine	3,421	502	2,713	78	2,508	2,116
N. H	2,980	227	2,502	75	2,132	1,876
Vt	1,472	391	979	74	1,020	724
Mass	5,481	505	4,560	74	3,878	3,374
R. I	697	71	579	79	520	457
Conn	4,080	406	3,315	76	2,921	2,519
N. Y	21,724	4,249	15,370	68	13,600	10,452
N. J	8,546	754	6,685	84	6,646	5,615
Pa	27,424	5,397	18,765	72	18,031	13,511
Ohio	32,142	7,727	20,914	62	18,372	12,967
Ind	28,399	7,389	18,236	60	15,884	10,942
Ill	37,035	9,876	23,366	65	22,195	15,188
Mich	18,371	4,706	11,712	66	11,244	7,730
Wis	22,675	6,409	13,456	55	11,467	7,401
Minn	25,390	7,078	15,284	56	13,099	8,559
Iowa	45,090	9,165	31,354	63	25,994	19,753
Mo	31,982	12,004	17,786	53	15,470	9,427
N. D	5,492	2,491	2,313	52	2,622	1,203
S. D	10,402	3,295	5,248	57	5,498	2,991
Neb	20,557	6,222	12,322	55	10,441	6,777
Kan	27,698	9,759	16,378	49	12,531	8,025
Del	3,856	496	3,089	66	2,377	2,039
Md	7,030	2,038	4,444	63	4,019	2,800
Va	18,992	8,003	9,445	52	9,269	4,911
W. Va	5,603	2,477	2,603	52	2,668	1,354
N. C	14,212	8,484	4,209	46	6,050	1,936
S. C	7,066	4,272	2,242	45	2,961	1,009
Ga	11,011	6,805	3,112	44	4,460	1,369
Fla	2,708	1,201	1,116	58	1,393	647
Ky	16,990	8,291	7,310	49	7,695	3,582
Tenn	15,266	6,459	7,444	46	6,408	3,424
Ala	10,472	5,836	3,487	35	3,364	1,220
Miss	9,471	5,917	2,809	37	3,206	1,039
Ark	8,618	4,760	2,940	44	3,428	1,294
La	5,748	4,092	981	47	2,431	461
Okla	17,331	8,313	7,371	47	7,546	3,464
Tex	29,320	14,662	10,863	42	11,180	4,562
Mont	2,853	1,554	1,083	49	1,285	531
Idaho	3,271	1,290	1,626	48	1,445	780
Wyo	1,095	624	421	54	543	227
Colo	4,005	1,765	2,082	54	1,925	1,124
N. Mex	1,078	514	461	48	459	221
Ariz	992	233	616	62	564	382
Utah	3,051	532	2,184	43	1,192	939
Nev	347	80	237	52	164	123
Wash	10,612	2,449	6,923	44	4,295	3,046
Ore	4,646	1,821	2,411	47	2,005	1,133
Calif	27,446	3,253	20,004	52	13,237	10,402
U. S	624,148	204,844	355,350	57.9	321,642	205,626

TABLE 64.—ESTIMATED FARM VALUE, GROSS INCOME, AND CASH INCOME FROM EGGS IN 1935
(U. S. Department of Agriculture)

State	Laid, millions of eggs	Home consumption, millions of eggs	Sold, millions of eggs	Farm price per doz., cents	Farm value, thousands of dollars	Cash income, thousands of dollars
Maine	184	33	144	31.4	4,815	3,768
N. H.	128	16	106	33.7	3,595	2,977
Vt.	79	25	51	29.7	1,955	1,262
Mass.	242	29	202	36.0	7,260	6,060
R. I.	35	5	29	34.3	1,000	829
Conn.	206	22	176	33.8	5,802	4,957
N. Y.	1,323	238	1,042	29.2	32,193	25,355
N. J.	498	43	438	31.8	13,197	11,607
Pa.	1,616	243	1,318	26.4	35,552	28,996
Ohio	1,625	284	1,277	23.5	31,822	25,007
Ind.	1,165	231	877	21.9	21,261	16,005
Ill.	1,534	377	1,083	21.9	27,996	19,765
Mich.	986	242	707	23.7	19,474	13,963
Wis.	1,285	289	951	23.0	24,630	18,228
Minn.	1,251	283	917	21.4	22,309	16,353
Iowa	2,237	460	1,687	21.3	39,707	29,944
Mo.	1,729	302	1,363	20.7	29,825	23,512
N. D.	227	130	86	20.1	3,802	1,440
S. D.	418	141	256	20.5	7,141	4,373
Neb.	915	264	610	20.2	15,402	10,268
Kan.	1,311	270	986	20.2	22,068	16,597
Del.	135	15	112	25.4	2,858	2,371
Md.	373	48	311	25.2	7,833	6,531
Va.	742	165	539	23.0	14,222	10,331
W. Va.	319	85	223	22.8	6,061	4,237
N. C.	432	243	161	23.0	8,280	3,086
S. C.	176	102	60	23.0	3,373	1,150
Ga.	346	180	144	23.0	6,632	2,760
Fla.	159	44	110	27.1	3,591	2,484
Ky.	617	255	328	20.7	10,643	5,658
Tenn.	639	220	388	20.4	10,863	6,596
Ala.	401	218	162	20.4	6,817	2,754
Miss.	319	193	107	20.1	5,343	1,792
Ark.	368	191	160	20.4	6,256	2,720
La.	227	142	74	21.1	3,991	1,301
Okla.	731	320	376	20.1	12,244	6,928
Tex.	1,509	692	758	20.6	25,905	13,013
Mont.	134	81	47	23.1	2,580	905
Idaho	168	56	105	21.5	3,010	1,881
Wyo.	56	28	26	24.8	1,157	537
Colo.	250	99	143	22.6	4,708	2,693
N. Mex.	72	32	38	24.6	1,476	779
Ariz.	55	11	42	29.3	1,343	1,026
Utah	254	31	217	22.9	4,847	4,141
Nev.	24	7	16	26.0	520	347
Wash.	761	113	627	23.7	15,030	12,388
Ore.	310	70	231	22.7	5,864	4,370
Calif.	1,682	165	1,462	25.2	35,322	30,702
U. S.	30,253	7,733	21,273	23.4	581,575	414,112

large quantities of eggs and poultry meat are shipped in from other more extensive producing sections.

The third section comprises the Pacific Coast states. In this section commercial poultry farming has been developed very extensively, and considerable quantities of eggs are shipped East annually.

The fourth section comprises the southern group of states, a section where the poultry industry is relatively undeveloped. There is very little specialization, and the farm flocks are small in size, so that production in several of these states frequently does not meet the local demand. Dis-

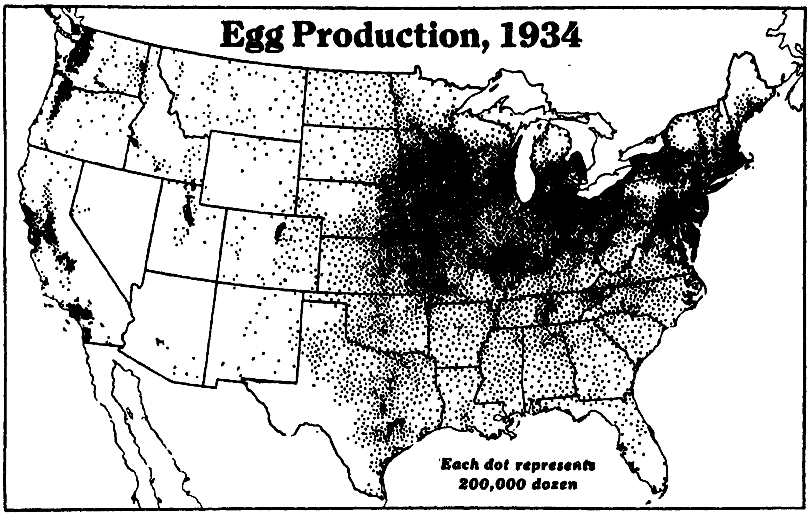

FIG. 200.—The bulk of the eggs are produced in the Middlewest, although there are important commercial producing centers in the Northeast and on the Pacific Coast. (*U. S. Dept. Agr.*)

tance from the more important consuming centers has been a factor retarding development as compared with other sections. The tardy development of agriculture as a whole and the general reliance upon cotton and tobacco as sources of farm income have been the major factors that have prevented the normal development of the poultry industry. These conditions are being remedied, however, and at present poultry production is being increased.

POULTRY RAISING A FARM INDUSTRY

The poultry industry of the United States is essentially a farm industry. The size of the flock per farm varies from those farms where only as many chickens are kept as will supply the home table with eggs and poultry meat to those where the flock is of sufficient size to contribute an important share toward the total farm income. There are numerous commercial flocks, but there is a great preponderance of small-sized flocks, as shown by the data in the table giving for 1930 the percentage of

chickens 3 months old and over in each size group and for 1929 the percentage of eggs produced by each group of flock size.

TABLE 65.—PER CENT OF FARMS REPORTING CHICKENS APR. 1, 1930, PER CENT OF CHICKENS RAISED IN 1930, AND PER CENT OF EGGS PRODUCED IN 1929, EACH ACCORDING TO SIZE OF FLOCK

Size of flock	Farms reporting 1930, per cent	Chickens raised 1930, per cent	Eggs produced 1929, per cent
Under 50	54.9	17.8	17.1
50 to 99	22.1	20.4	19.5
100 to 199	16.0	28.8	27.1
200 to 399	5.7	19.6	19.2
400 to 699	0.9	5.9	7.0
700 to 999	0.2	2.2	2.9
1,000 to 2,499	0.2	3.4	4.6
2,500 and over	Less than 0.05	1.8	2.2

The data in the table show that approximately 55 per cent of the farms reporting chickens in 1930 had flocks of less than 50 chickens per flock, 77 per cent had flocks of less than 100, and 93 per cent had flocks of less than 200. It is also shown that 38.2 per cent of all chickens on farms were in flocks under 100 in size and 67 per cent were in flocks under 200 in size. Also, 36.6 per cent of the eggs produced in 1929 were from flocks under 100 in size, and 63.7 per cent of the eggs produced in 1929 were from flocks under 200 in size. Flocks containing 400 or more birds per flock were responsible for approximately 17 per cent of the total egg production. On thousands of farms having flocks of less than 50 birds per flock no eggs or poultry meat is sold.

Shifts in Production.—Notwithstanding the fact that in the four geographical sections poultry raising is essentially a farm industry, during the past several years the average size of the flocks and the average egg production per farm have increased to a marked extent. The increase has been relatively greater in some sections than in others.

During the 25-year period from 1909 to 1934 there has been a tendency for the average number of chickens raised per farm in the Northeast to increase to a greater extent than in other sections of the country. In other words, the development of commercial poultry production has increased faster in the Northeast than in the rest of the country. In certain rather restricted areas in Oregon, California, and Washington there has also been a marked development in commercial poultry production. In the Middle West the growth of the industry has been remarkable, and there has been a tendency for many of the farm flocks to approach the size of commercial flocks. The changes in the average

number of chickens raised per farm in the South have been much less pronounced, many of the states actually showing a decrease in 1934 as compared with 1909.

TABLE 66.—THE 10 LEADING STATES IN THE AVERAGE NUMBER OF CHICKENS RAISED PER FARM
(Termohlen and Warren, 1936)

1909		1934	
1. Kansas	168	1. Delaware	763
2. New Jersey	160	2. New Jersey	418
3. California	160	3. New Hampshire	334
4. Iowa	154	4. Massachusetts	331
5. Delaware	150	5. California	283
6. Nebraska	146	6. Connecticut	274
7. Rhode Island	142	7. Rhode Island	273
8. Illinois	142	8. Iowa	217
9. Missouri	132	9. Nebraska	212
10. Maryland	130	10. Kansas	201

The relative advancement made by the Northeast is indicated in the table showing the 10 leading states in the average number of chickens raised per farm in 1934 as compared with 1909. It is interesting to observe that although Kansas dropped from first place in 1909 to tenth place in 1934, the increase in the average number of chickens raised per farm was considerable, being from 168 to 201, or an increase of almost 20 per cent. Delaware moved up from fifth place in 1909 to first in 1934, the relative increase amounting to over 400 per cent. Other northeastern states also had relatively great increases, due in part to the rapid expansion of the broiler industry. Aside from the broiler-producing areas, the average number of chickens raised per farm is a good index of the average size of laying flocks maintained per farm, because chicks are raised largely for replacement purposes.

The marked increase in the average size of the laying flocks per farm that has taken place in the country as a whole indicates a marked increase in the average number of eggs produced per farm. As a matter of fact, the increase in egg production has been relatively greater than the increase in size of laying flocks, largely because of improved methods of breeding and other factors, as pointed out previously.

During the 35-year period from 1899 to 1934, the relative position of the states changed considerably on the basis of the average number of dozens of eggs produced per farm. Among the 10 leading states in 1899 there were 4 northeastern ones whereas in 1934 there were 6, and, for the most part, their relative standing was higher. The following 5 were among the 10 leading states in 1899 and 1934: New Jersey, California,

Massachusetts, Rhode Island, and Delaware. In 1899 Kansas, Iowa, South Dakota, Nebraska, and Ohio were among the 10 leading states, but

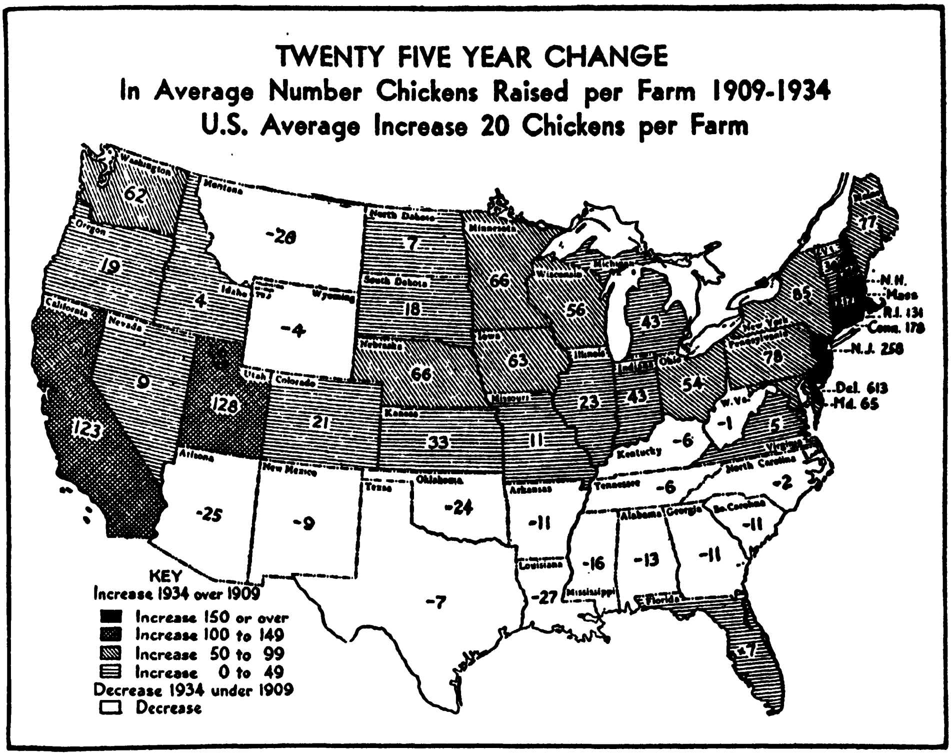

FIG. 201.—The average number of chickens raised per farm increased to a much greater extent in some states than others during the 25-year period from 1909 to 1934. Note the marked increase in certain northeastern states. (*Termohlen and Warren*, 1936.)

in 1934 their places were taken by Utah, New Hampshire, Washington, Connecticut, and New York.

TABLE 67.—THE 10 LEADING STATES IN AVERAGE NUMBER OF DOZEN EGGS PRODUCED PER FARM

(Termohlen and Warren, 1937)

1899		1934	
1. Rhode Island	661.2	1. New Jersey	1717.8
2. Kansas	468.7	2. California	1370.2
3. Iowa	463.7	3. Massachusetts	1187.1
4. California	440.6	4. Utah	995.1
5. Massachusetts	423.8	5. New Hampshire	989.1
6. South Dakota	387.6	6. Washington	971.0
7. New Jersey	385.8	7. Rhode Island	885.9
8. Delaware	383.6	8. Connecticut	871.8
9. Nebraska	379.1	9. Delaware	763.9
10. Ohio	357.3	10. New York	755.2

The fact of outstanding importance is the relative increase in egg production indicated. In the case of the 5 states that were among the 10 leading ones in 1899 and 1934 the per cent increase in egg production per farm was as follows: New Jersey, over 340; California, over 210; Massachusetts, over 180; Delaware, over 99; and Rhode Island, about 34. The increase in the average number of dozens of eggs produced per farm in Utah, New Hampshire, Washington, Connecticut, and New York was very great. Even in the 5 states—Kansas, Iowa, South Dakota, Nebraska, and Ohio—that were among the 10 leading in 1899 but not in

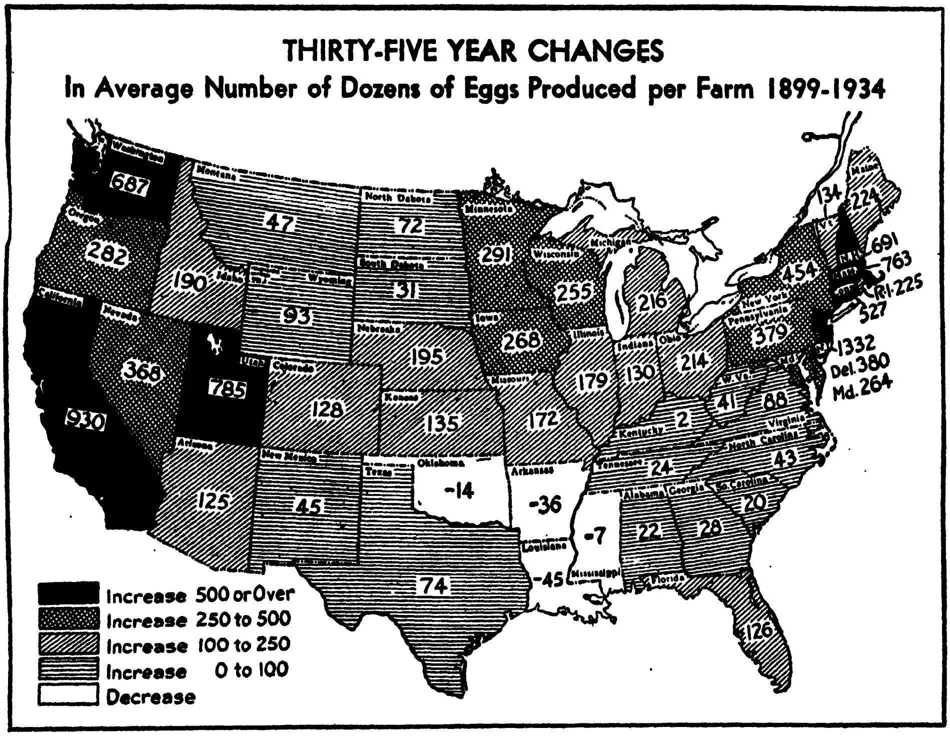

FIG. 202.—During the 35-year period from 1899 to 1934, the increase in the average number of dozens of eggs produced per farm was much greater in certain states of the far east and the far west than in other states. (*Termohlen and Warren*, 1937.)

1934, the increase in egg production was relatively great. By way of contrast, the southern states showed relatively the least increase in egg production during the 35-year period, Arkansas, Louisiana, Mississippi, and Oklahoma actually showing decreases, the situation of Oklahoma undoubtedly having been affected by the severe drought of 1934. The development of commercial egg-producing plants has assumed greatest proportions in the northeastern states and in certain other states, particularly Utah, Oregon, California, and Washington.

The figures relating to the increased number of chickens raised per farm and the increased egg production per farm bear mute testimony to

the increased volume of poultry meat and eggs produced when it is realized that the census data indicate that during recent years approximately the same number of farms was engaged in the poultry enterprise. This remarkable development of the poultry industry has been accompanied by an increase in the economic complications of various branches of the industry. The numerous economic factors involved in the reproduction of the flocks and in poultry, meat, and egg production as well as in the marketing of poultry products should be given the fullest possible consideration by those interested in the industry.

ECONOMIC FACTORS IN REPRODUCTION

One of the remarkable developments of the poultry industry in the United States has been the expansion of the breeder and commercial-

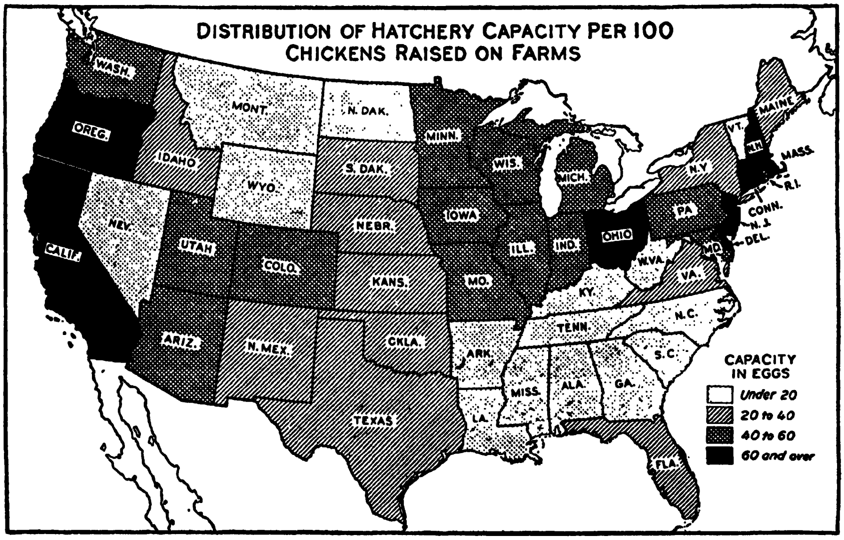

FIG. 203.—Hatchery capacity, July 1, 1934, per 100 chickens raised on farms in 1933, by states. (*Warren and Wermel*, 1935.)

hatchery industry, as pointed out in the chapter on Incubation Principles and Practices. For the country as a whole it would appear that well over 50 per cent of the chickens that are raised on farms and commercial poultry plants are hatched in breeder and commercial hatcheries, a breeder hatchery being designated as one in which all chicks hatched are hatched from eggs produced by the operator's flock, and commercial hatcheries being designated as those that purchased hatching eggs from flocks not owned by the operator. Practically all of the broilers that are produced on commercial broiler-producing plants are hatched in commercial hatcheries.

No data are available on the costs of producing chicks for replacement purposes by the natural method of incubation. Data are available, however, on the costs of reproduction in commercial hatcheries.

The factors of cost in incubating eggs include the value of the eggs incubated, labor, fuel, the use of the incubators, and other miscellaneous

COST OF PRODUCING AND AVERAGE SELLING PRICE OF 100 CHICKS

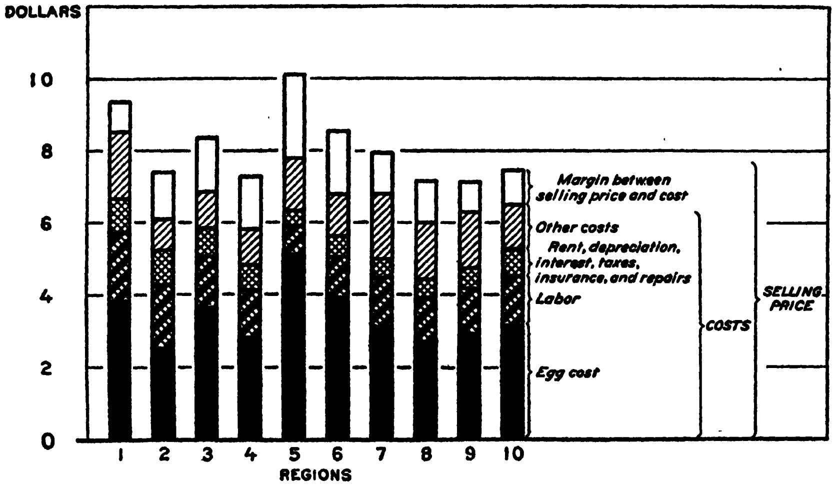

FIG. 204.—Showing the different elements of hatching cost and the margin between the average cost of producing 100 chicks and the average selling price, by 10 regions, 1934. The regions included the following states: 1, Montana, Wyoming, Colorado, Arizona, and states to the west of them; 2, New Mexico, Texas, Oklahoma, Arkansas, and Louisiana; 3, Mississippi, Tennessee, Kentucky, North Carolina, and other southeastern states; 4, North and South Dakota, Nebraska, Kansas, and Colorado; 5, New York, Connecticut, and other northeastern states; 6, Pennsylvania, West Virginia, Virginia, District of Columbia, Maryland, Delaware, and New Jersey; 7, Ohio; 8, Indiana and Illinois; 9, Iowa and Missouri; 10, Minnesota, Wisconsin, and Michigan. (*Warren and Wermel*, 1935.)

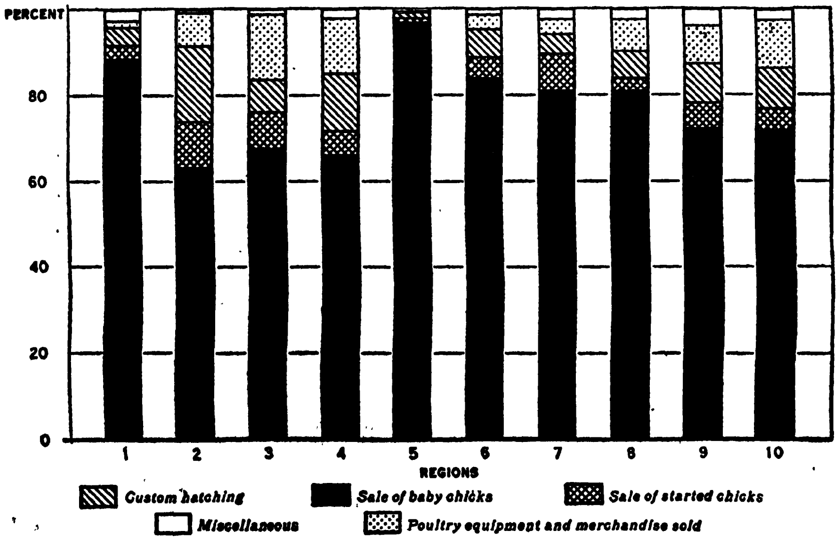

FIG. 205.—Sources of hatchery income, 1934, by 10 regions. (*Warren and Wermel*, 1935.)

items. In a survey of 110 hatcheries in Maryland for the period of July 1, 1936, to June 30, 1937, it was found that, on the average, the

investment in incubators amounted to 67.5 per cent of the total investment and the investment in buildings amounted to 23.6 per cent of the total investment. The cost of the eggs amounted to 62.6 per cent of the total cost of hatching. Hatchery overhead costs and general overhead costs amounted to 10 per cent of the total cost of hatching. The three most important cost factors in hatching, the cost of the eggs, hatchery overhead costs, and general overhead costs, amounted to 87.5 per cent of the total costs of hatching. The value of the chicks sold from these commercial hatcheries in Maryland accounted for 91.8 per cent of the total income received by the hatcheries.

In an economic survey of the hatchery industry of the United States conducted by the U. S. Department of Agriculture it was found that among 683 hatcheries located in different parts of the country, 81.2 per cent of their total income was obtained from the sale of baby chicks and 18.8 per cent from custom hatching, selling "started" chicks, poultry feed, and supplies.

The average hatchability of these 683 hatcheries in 1934 was 64.4 per cent. The cost of incubation per chick is affected greatly by the hatching percentage secured, as shown by observations made in the state of Washington.

TABLE 68.—EGG COST PER CHICK IN RELATION TO HATCHING PERCENTAGE
(Carver and Buchanan, 1926)

Hatchery No.	Eggs set	Chicks hatched	Per cent hatch	Egg cost per chick, cents
1	49,117	25,365	52.0	8.1
2	273,200	154,950	57.0	7.4
3	115,200	68,000	59.0	7.1
4	378,000	223,000	60.0	6.8
5	40,318	25,100	62.0	6.7
6	16,000	10,000	62.5	6.7
7	24,500	18,000	73.0	5.7
8	29,000	22,000	76.0	5.5

The data in this table show that the higher the hatchability the lower the egg cost per chick hatched. In the U. S. Department of Agriculture survey of 683 hatcheries it was found that the cost of eggs amounted to 50.6 per cent of total costs of hatching, labor amounting to 18.4 per cent of the total costs; these two items constituted, respectively, the most important cost factors in the hatchery business.

Since egg costs constitute the most important single cost factor in hatching, and since the hatchability of eggs is such an important factor in determining the egg cost per chick, it is interesting to ascertain the

relationship that exists between the premium paid for hatching eggs and their hatchability. Most hatcheries pay a premium above market price, the amount of the premium differing greatly and depending upon the extent to which flock-improvement work is carried on among the flocks producing the eggs for the hatchery.

The accompanying chart may be used for calculating the egg cost per 100 chicks when the per cent of salable chicks hatched and the cost of the eggs in cents per dozen are known. The range in hatchability is indicated by the vertical line at the left side of the chart, the line being graduated

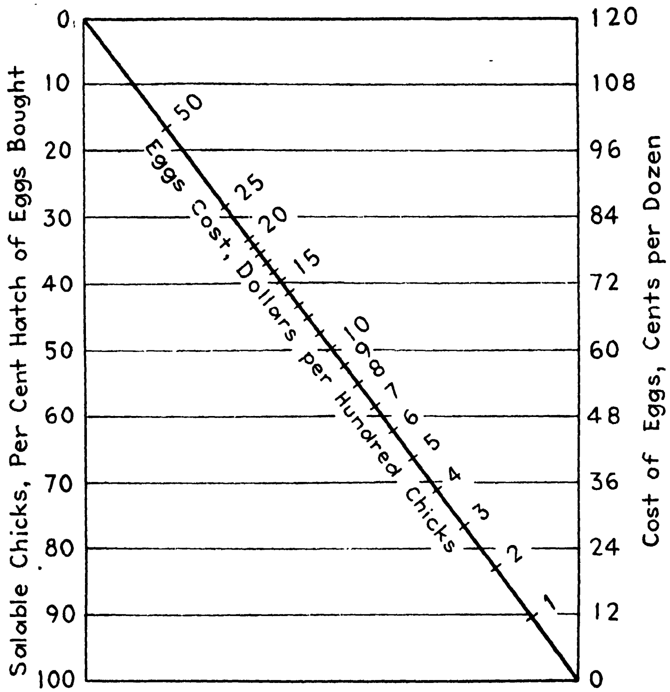

FIG. 206.—A chart for the easy calculation of the egg cost per 100 chicks when the per cent of salable chicks hatched and the cost of eggs in cents per dozen are known. (*Byerly*, 1936.)

from 100 at the bottom to 0 at the top. The range in price paid for eggs in cents per dozen is indicated by the vertical line at the right side of the chart, the line being graduated from 0 at the bottom to 100 at the top. The diagonal line extending between the 0 points of the two vertical lines is graduated from 1 to 50 and indicates the egg cost per 100 chicks expressed in terms of dollars per 100 chicks.

Placing a ruler across the chart and crossing the vertical lines at the right and left sides at the appropriate price per dozen for eggs and the appropriate per cent hatch of salable chicks gives the egg cost per 100 chicks on the diagonal line. If hatching eggs cost 48 cts. per dozen and 78 per cent of them hatch into salable chicks, the egg cost per 100 chicks

is $5; but if 45 per cent hatch into salable chicks, the egg cost per hundred chicks is $8.

This chart may also be used to compute the premium, over the market price, that the hatchery operator can afford to pay for eggs. He knows the selling price of his chicks and should know the required overhead and profit to be charged to each 100 chicks. Suppose that chicks sell for $10 per 100, that the hatchery operator requires a profit of $2 per 100 chicks and that his overhead amounts to $3 per 100 sold. This leaves $5 per 100 as the permissible egg cost per 100 chicks. By placing the

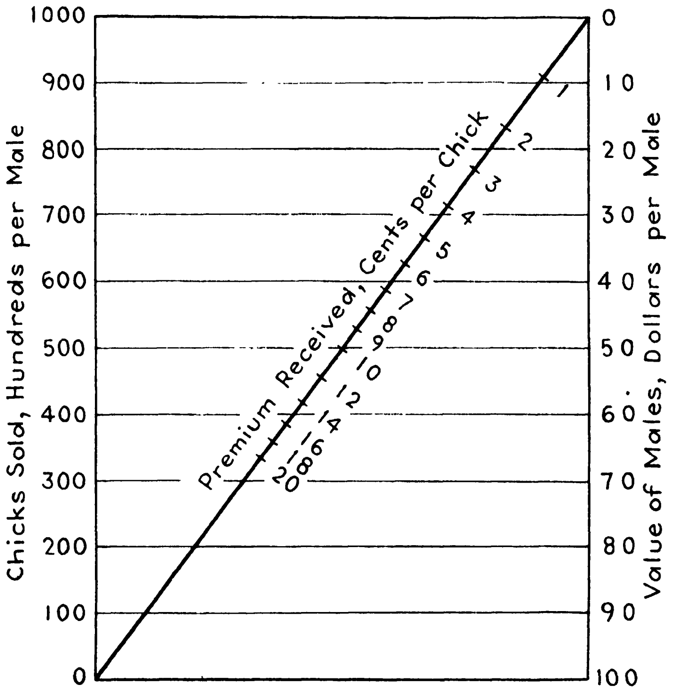

FIG. 207.—A chart for determining the relationship among the three factors, salable chicks hatched per male, the value of male breeders in dollars, and the premium in cents per chick. (*Byerly*, 1936.)

edge of the ruler at the $5 point on the diagonal line and also at the point on the line at the left side representing the per cent hatch obtained, the price the hatchery operator can afford to pay for eggs will be read at the point at which the edge of the ruler intersects the line on the right side. The difference between this price and the market price of eggs is the premium that the hatchery operator can afford to pay.

Many breeders and hatchery operators are faced with the problem of determining the price they should pay for male birds of superior breeding worth. The chart above has been designed to assist in determining the relationship among the three factors: salable chicks hatched per male, the value of the male, and the premium in cents per chick. This second

chart was constructed so that the vertical line on the left is graduated to indicate salable chicks sired by a male; the diagonal line graduated to show the premium obtained because of the use of the male, expressed in cents per chick; and the vertical line on the right to show value of the male in dollars. Given any two of the three values just stated, it is possible to obtain the third by placing the edge of a ruler through the two known values; the third may then be read directly.

Both charts may be used to supplement each other in determining the influence of hatchability, for the number of salable chicks produced is obviously greatly affected by hatchability, and the premium that may be paid on eggs bought depends directly on hatchability. If a premium of $4 per 100 chicks is obtained through the use of superior males, then this value may be substituted on the diagonal line of the first chart for the $4 point for egg cost of chicks; and by passing the straightedge through this point and through the point representing the hatchability obtained, the premium that may be paid per dozen eggs is read directly on the vertical line at the right of the chart. For example, if the hatchability was 70 per cent, then a premium of about 34 cts. per dozen may be paid for the use of the superior male.

ECONOMIC FACTORS IN BROILER PRODUCTION

The many millions of pounds of poultry meat produced in the United States each year reaches the consumer principally as broilers, fryers, roasters, and fowl, the first three classes constituting the chickens raised each year, and fowl representing the layers that are marketed after having served their usefulness. Most of the fryers, roasters, and fowl are produced on general farms, where the poultry enterprise is considered a side line of the farming operations. For these classes of chickens very few data of an economic character have been assembled, those available being limited, for the most part, to the costs involved in brooding.

The cost of brooding chicks is an important problem which has received very little attention. Apparently no records have been kept or are available concerning all cost factors, such as investment in the brooder house and labor and overhead expenses, in addition to the actual fuel costs. A few records do exist relating to the amount and cost of fuel consumed during the brooding period.

In a study conducted in New Jersey in 1924 with 19 coal-stove brooders, each brooding from 250 to 300 chicks, it was found that the amount of coal burned per stove daily was 16.9 lb. The fuel cost per chick for Plymouth Rock and similar breeds was 3.5 cts. up to 8 weeks of age, after which no more heat was necessary. For chicks of the Leghorn and similar breeds the fuel cost per chick was 1.1 cts. up to 6 weeks of age, after which no more heat was used.

A survey of fuel costs conducted in California in 1923 with coal valued at \$26 per ton, coal oil at 15 cts. per gallon, gas at 9 cts. per cubic foot, and electricity at 4 cts. per kilowatt-hour gave the following results for brooding chicks for 50 days in lots of 250 chicks: with the use of electricity, \$3.14; with use of coal oil, \$3.44; with the use of coal, \$3.55; with the use of gas (in hot-water pipe system), \$1.94. It should be borne in mind that the cost of coal is much higher in California than in most other parts of the country.

In Oregon in 1927 it was found that in electric brooding with electricity at 2 cts. per kilowatt-hour, when radiation was depended upon as the method of heat transfer, the heating cost averaged about 2.5 to 3 cts. per chick each 1,000 hr.; and in brooders depending upon convection the heating cost averaged about .75 to 1 ct. per chick.

Observations made at Cornell University indicate that the amount of electric energy used in brooding chicks varied with the season. The following figures give the electric energy used in brooding chicks in lots of 250 chicks per 440-watt electric brooder, the chicks being confined to the house and sun porches for 8 weeks:

	Kilowatt-hours
Apr. 27 to June 22, 1933	201
Oct. 18 to Dec. 14, 1933	390
Feb. 3 to Mar. 31, 1934	412
Jan. 4. to Mar. 2, 1935	375
Mar. 8 to May 3, 1935	302

These data have a direct bearing on the cost of producing broilers, which has become an important commercial enterprise in certain sections of the country.

At the present time the principal commercial-broiler-producing states in the order of their importance are Delaware, Virginia, Maryland, Connecticut, New York, California, Georgia, Pennsylvania, Indiana, and Arkansas. Approximately 66 per cent of the total number of commercially produced broilers is raised in four or five counties of the Eastern Shore of Maryland, the two southern counties of Delaware, and one county in Virginia adjoining Maryland. There are approximately 1,350 commercial broiler producers in this section, which is known as the "Delmarva region."

Commercial broiler production is usually carried on in conjunction with other enterprises, the size of the broiler flock varying from about 1,000 to over 100,000 birds. Many of the operators raise two or three lots of broilers each year, thereby increasing the efficiency of labor, equipment, and investment.

In an economic study of the broiler industry of Maryland conducted by the Experiment Station, covering the broiler-producing years 1934 to

1935 and 1935 to 1936, it was found that most of the operators normally start their new year any time from August to January. More broiler producers started their yearly operations in January than any other month, with February second, October third, and September fourth. The study was based on 109 and 122 broiler plants, respectively, in each of the two broiler years.

Most of the broilers produced are either purebred Barred Plymouth Rocks or crossbreds from matings of Barred Plymouth Rock males and New Hampshire or Rhode Island Red females. The crossbred birds are barred, since the barring factor is transmitted from the sire to the cock-

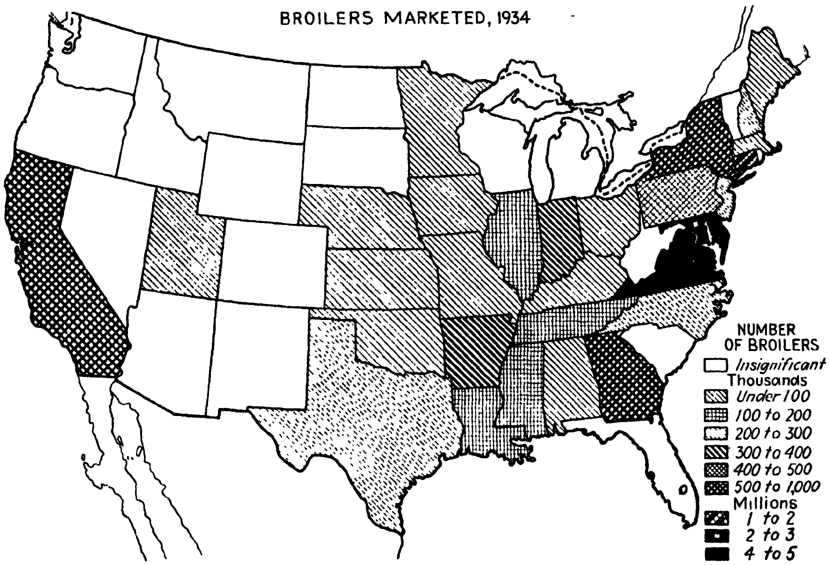

FIG. 208.—The principal broiler-producing States, based on the approximate number of broilers marketed in 1934, are Delaware, Virginia, Maryland, Connecticut, New York, California, Georgia, Pennsylvania, Indiana, and Arkansas. (*Termohlen, Kinghorne, Warren and Radabaugh*, 1936.)

erels and pullets. The reason that broilers with barred plumage are produced is because the New York broiler market frequently pays higher prices for broilers with barred feathers than for others, practically all of the broilers being sold alive.

The age at which the broilers were sold varied from 10 to 18 weeks, the average being 13.5. At selling time the weight of the broilers varied from 1.5 to 3.5 lb., the average being 2.7.

Distribution of Investment.—The average commercial broiler plant in Maryland consists, for the most part, of a long shed-roof brooder house or houses with small yards in front. The houses are simple in design, and coal-burning brooder stoves are used for brooding. The investment items were distributed as shown in Table 69.

TABLE 69.—DISTRIBUTION OF INVESTMENT IN COMMERCIAL BROILER PLANTS IN MARYLAND
(Poffenberger and De Vault, 1937)

Investment item	Average per plant	Average per 100 broilers produced	Per cent of total
Brooder houses	$ 975.00	$11.48	69.9
Brooders	214.80	2.53	15.4
Feed and water equipment	85.59	1.00	6.1
Land	63.67	0.75	4.5
Machinery	22.76	0.27	1.6
Fencing	21.31	0.25	1.6
Miscellaneous	11.84	0.14	0.9
Totals	$1,294.97	$16.42	100.0

The investment in brooder houses and brooders amounted to 85.3 per cent of the total, all other items being comparatively small. The amount of land used was only 1.4 acres per farm.

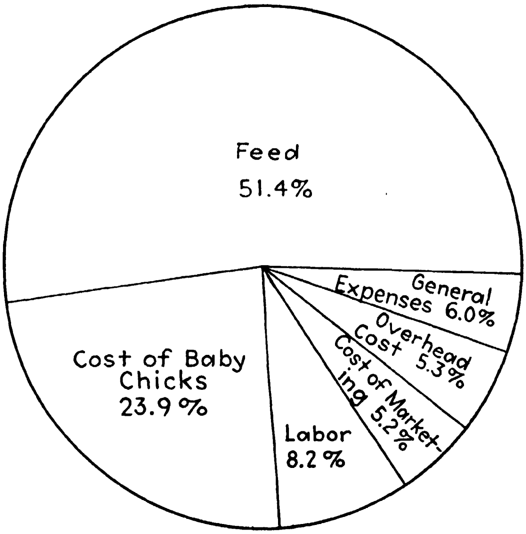

FIG. 209.—Showing the percentage distribution of the cost of producing and marketing broilers in Maryland, two-year average costs, 1934–1936. (*Poffenberger and DeVault*, 1937.)

Distribution of Expenses.—The total cost of producing broilers commercially in Maryland is shown in Table 70. Feed was the most important item of expense, with the cost of baby chicks second, these two items constituting over 80 per cent of the total cost.

It should be pointed out that the total operating costs in broiler production from the time the baby chicks were purchased until the broilers

were finally disposed of included the cost of marketing the broilers, which amounted to about 5 per cent of all operating costs. This item is discussed in a later section of this chapter.

TABLE 70.—DISTRIBUTION OF EXPENSES IN PRODUCING BROILERS COMMERCIALLY IN MARYLAND
(Pfoffenberger and De Vault, 1937)

Expense item	Average per plant	Average per 100 broilers produced
Feed	$2,133.32	25.11
Baby chicks	988.29	11.64
Labor:		
Hired labor	92.39	1.09
Family labor	245.78	2.89
General expenses:		
Fuel	187.76	2.21
Litter	41.55	0.49
Disinfectants	9.44	0.11
Light	7.55	0.09
Water	5.36	0.06
Overhead costs:		
Interest	69.96	0.82
Depreciation	64.95	0.77
Repairs	52.87	0.63
Taxes	17.27	0.20
Insurance	13.83	0.16

Factors Affecting Income.—The gross income from these Maryland broiler plants amounted to $4,630.21 per plant, or $54.51 per 100 broilers produced. The sale of broilers accounted for 97.3 per cent of the total income, the increase in inventory for 2.2 per cent, and the home consumption of broilers for 0.5 per cent. The net income obtained was affected by a large number of factors, some of the most important including feed cost per broiler, chick cost per broiler sold, volume of business done, the weight of the broilers when sold, mortality, and the breeding of the broilers.

Feed Cost per Broiler.—Since the cost of feed accounts for approximately 50 per cent of the total cost of producing broilers, it is obvious that unless a properly balanced diet is used and proper feeding methods are employed, possible profits in broiler production may be turned into losses. It was found that where the average feed costs per broiler amounted to 30 to 35 cts., practically no profit was made. When the average feed cost per broiler amounted to over 35 cts., the operator lost money. The greatest profit per broiler was made when the feed costs ranged from 20 to 24.9 cts. per broiler.

Chick Cost per Broiler Sold.—The results of the study indicated that it did not pay operators to secure low-quality chicks. Operators buying chicks at 10 cts. or more per chick made greater profits per broiler sold than those who bought chicks at less than 10 cts. per chick.

Volume of Business.—It was found that operators producing on the average between 5,000 and 15,000 broilers in one or two lots per year made a larger profit per broiler than those producing fewer broilers in one or two lots or more broilers in three or four lots per year.

Weight of Broilers.—For the most part, operators who sold broilers weighing less than 2.5 lb. lost money; whereas when the average weight of the broilers increased up to about 3 lb., the gross income, cost of production, and net income per broiler increased.

Mortality.—On broiler plants where there was a mortality of 25 per cent or more, the operator lost money. Very little money was made when the mortality ranged from 15 to 24 per cent. There were several operators who had less than 8 per cent mortality in their broilers, although the average mortality among the broilers produced by all operators amounted to 15.5 per cent.

During the first 2 weeks 40.7 per cent of the total mortality occurred; during the third to the end of the sixth week, 29.6 per cent; during the seventh to the end of the ninth week, 18.2 per cent; from the tenth week to selling time, 8.8 per cent; and the loss by accident was 2.7 per cent of the total mortality.

Crossbred versus Purebred Broilers.—A very interesting observation made in connection with the Maryland study pertains to the results secured from crossbred and from purebred broilers. There were 84 broiler plants that produced crossbred and 87 that produced purebred broilers, the total numbers involved being over 800,000 and over 600,000, respectively.

Better results were secured from the crossbreds than from the purebreds, largely because of the following factors: less mortality, slightly faster growth as indicated by somewhat heavier weight at selling time at 12.6 weeks of age for crossbreds as compared with 13.7 weeks of age at selling time for purebreds, less feed per pound of gain, and a little higher selling price per pound.

ECONOMIC FACTORS IN EGG PRODUCTION

Among the 5,500,000 and more farms in the United States on which poultry are raised, those obtaining 40 per cent or more of the total value of all products of the farm from the poultry enterprise are classified by the Bureau of the Census as poultry farms. On this basis there are probably about 200,000 poultry farms, several thousand of which obtain practically all of the farm income from poultry and poultry products.

The average number of layers in the general-farm flock is probably in the neighborhood of 70, and in poultry-farm flocks about 350. The increased egg production and profits per bird that are usually obtained from the poultry-farm flock, as compared with the general-farm flock, are accounted for by the adoption of better methods of breeding, feeding, and management and better care of the products in spite of the fact that the average cost of feed per bird is usually greater in the case of the poultry-farm flock.

Regardless of the size of the flock, profits in the poultry enterprise depend largely on a favorable relationship existing between production costs and receipts obtained, some of the factors affecting the relationship being beyond the control of the producer, while others are definitely within his control. For instance, the producer has little control over the price of feed or the price of eggs, but he can control to a considerable extent such factors as average egg production per bird, the utilization of labor, and mortality.

On the general farm where about 200 laying birds are maintained from year to year, feed is the most important cost factor in producing eggs, and the average number of eggs produced per bird is the most important factor affecting the labor income obtained, labor income being regarded as the amount by which income exceeds expenses other than for the farmer's and the family labor. The importance of high egg production in determining labor income is well demonstrated in the results secured from 1334 farm flocks in Missouri over a period of 10 years, various breeds of chickens comprising the flocks.

TABLE 71.—THE RELATION BETWEEN EGG PRODUCTION AND TOTAL INCOME, TOTAL EXPENSES, AND LABOR INCOME PER HEN, RESPECTIVELY, IN 1,334 FARM FLOCKS IN MISSOURI
(Winton and Canfield, 1930)

Average yearly egg production	Number of flocks	Total income per hen	Total expenses per hen	Labor income per hen
Under 100	130	$3.43	$2.02	$1.41
101 to 125	367	4.11	2.23	1.88
126 to 150	437	5.04	2.54	2.50
151 to 175	283	5.49	2.75	2.74
176 to 200	95	6.11	2.95	3.16
201 and over	22	9.34	3.67	5.67

When the flock assumes the proportions of a commercial flock from which the owner seeks to obtain the major share of his income, it is necessary to give full consideration to the more important factors influencing profits.

The Capital Investment.—The capital investment in a commercial-poultry plant varies greatly in different parts of the country, being influenced largely by the price of land and building materials and the cost of labor in construction work. Moreover, because of changing poultry practices, such as the all-year confinement of laying stock, the relative amount of money invested in land and buildings may change from time to time. Several state experiment stations have compiled data on the capital investment in commercial poultry farms in their respective states.

The data from different sources are in agreement in showing that the investment in laying houses and young stock and laying hens constitutes the major share of the total investment. The investment in laying houses varies from about 25 per cent of the total investment in some sections of the country to as high as 45 per cent in other sections. Likewise the investment in poultry varies from 25 to as high as 40 per cent of the total investment.

No set of figures for the different items of the capital investment could be given that would be applicable to any section of the country. The only suggestion that can be made is that the quality of the stock should be the best available and the houses should be so constructed as to give the most satisfactory results in order that the best possible returns may be secured from the total capital investment. At the same time the amount of money invested in machinery, equipment, and other items should receive the most careful consideration in order that the poultry plant may be placed on the most efficient operating basis.

Expense and Income Factors.—It is well for poultrymen to know which phases of their poultry operations are economically the most important in order that the business may be conducted most intelligently. Data compiled from surveys conducted in Oregon, California, New Jersey, and New York are somewhat typical of observations made in other states and are given here in terms of percentages, for the simple reason that price variations are sometimes so great from year to year and between different sections of the country that actual prices frequently have little meaning when applied to a local situation. Moreover, the relative importance of the different items of expense and income is of particular interest to the operator.

In Table 72 the Oregon data were compiled from 441 flock records made in 1926, 1927, and 1928; the California data, from numerous Sonoma County flock records in 1925; the New Jersey data, from 35 large-sized flock records obtained in 1933; and the New York data, from 32 flock records on Long Island in 1926.

It is quite obvious that feed is by far the most important single item of expense in commercial egg production. The next most important single factor is labor, including the operator's and hired. Other items,

some of which are relatively important, include interest, depreciation, water, taxes, and poultry bought. It follows, therefore, that the most intelligent operation of a commercial poultry plant involves good feeding practices and the efficient utilization of labor.

TABLE 72.—ITEMS OF EXPENSE IN OPERATING A POULTRY PLANT

Item	Per cent of total expenses			
	Oregon[1]	California[2]	New Jersey[3]	New York[4]
Feed	54	54	41	45
Labor	19	15	18	22
All others	27	31	41	33

[1] Scudder and coworkers, 1931.
[2] Buster and Fluharty, 1926.
[3] Waller and Carncross, 1934.
[4] Misner and coworkers, 1923.

The sources of income include the receipts obtained from market and hatching eggs and from poultry and poultry products, those from market eggs being by far the most important item on most commercial poultry plants except broiler- or other specialized meat-producing plants. Data from the same sources are given in the next table.

TABLE 73.—SOURCES OF INCOME IN OPERATING A POULTRY PLANT

Item	Per cent of total income			
	Oregon	California	New Jersey	New York
Market eggs	76	83	81	68
Hatching eggs	5	10	3	
Baby chicks	..	..	4	5
Breeding stock	..	..	..	5
Market poultry	8	4	11	18
All others	11	3	1	4

The income obtained from market eggs is determined by the number of eggs produced and their price, and the proportion of the income obtained from market eggs as compared with other sources of income depends largely upon the extent to which the operator sells hatching eggs or baby chicks and the value of the market poultry sold.

Factors Determining Labor Income.—From an analysis of data secured on 49 Connecticut poultry farms for the poultry year ending in the fall of 1935 it was found that the six most important factors determining labor income were: (1) average annual egg production per bird, (2) average number of eggs produced per bird during October and November, (3) laying-flock mortality, (4) efficient utilization of labor,

(5) efficient utilization of investment, and (6) size of business. In the Connecticut study the average number of laying birds housed was 1,191, and the average number of laying birds for the year was 867. Although the returns secured from these flocks are given in terms of dollars, the important fact for poultrymen to keep in mind is the relationship that exists between factors that determine differences in the returns secured, realizing that, if the records had been obtained for a different year, the actual returns secured would probably have been somewhat different.

Importance of Good Annual Egg Production.—It was found that good egg production was essential in securing a good labor income, although there were some flocks that laid well but gave a low labor income because of excessive labor costs, inefficiency in management, small-size business, or other reasons. All flocks that laid less than 150 eggs per bird provided a relatively low labor income unless the operators had a special market. On a hen-day basis the average egg production per bird was 164 eggs, the highest average production being 190 and the lowest 118 eggs.

TABLE 74.—LABOR INCOME IN RELATION TO ANNUAL EGG PRODUCTION (Putnam, 1935)

Average egg production per bird	Number of flocks	Labor income per flock
Under 150	10	$ 61
150 to 159.9	7	1,203
160 to 169.9	11	2,191
170 to 179.9	9	1,988
180 and over	12	2,656

The average number of eggs laid by a flock is determined largely by the breeding quality of the flock, relative freedom from disease, the feeding of well-balanced diets, and other methods of management. In many cases the proportion of pullets in the flock also has a bearing on the number of eggs produced. Pullets lay better on the average than yearling and older hens. It may also be pointed out that the better the bred-to-lay quality of the flock the less the amount of culling necessary in order to maintain the flock on an efficient basis of egg production.

Good Fall Production Necessary.—Since market-egg prices are relatively higher during the late summer and fall months than at other times, it is important to have the hens continue in production late in the fall. The Connecticut records demonstrate that the labor income obtained is definitely related to the average number of eggs laid during October and November.

TABLE 75.—LABOR INCOME IN RELATION TO EGG PRODUCTION DURING OCTOBER AND NOVEMBER
(Putnam, 1935)

Average egg production per bird, October and November	No. of flocks	Average yearly egg production per bird	Labor income per flock
15 or less	8	149	$ 52
15.1 to 20	17	158	1,364
20.1 to 25	14	170	1,699
25.1 and over	10	178	3,551

It appears that the average number of eggs laid per bird during October and November has a very important bearing on labor income. Furthermore, since persistence of production is related to first-year egg production, it is important that the flock be carefully culled during the summer and the best birds put under artificial light in a barracks house, as explained in the chapter on Feeding Practices.

High Mortality Lowers Income.—Many poultrymen overlook the relative effects of laying-flock mortality on labor income, the relationship between these two factors being brought out clearly in the Connecticut records.

TABLE 76.—LABOR INCOME IN RELATION TO MORTALITY
(Putnam, 1935)

Per cent mortality	No. of flocks	Average egg production per bird	Labor income per flock
20 and over	11	154	$ 666
10 to 20	22	164	1,330
Under 10	16	172	2,894

The data in these tables show that, for each 10 per cent decrease in laying flock mortality, the labor income per flock was practically doubled.

Efficient Utilization of Labor.—The utilization of labor is affected by a variety of factors, including the number of birds being cared for per man, the location and arrangement of the poultry houses, the convenience of facilities, and the planning and carrying out of the routine problems in management. Almost any two men given identical flocks under identical conditions would invariably get quite different results. The Connecticut records demonstrate that the best measure of labor efficiency was the amount of the receipts per $1 labor cost.

On many poultry plants there are too few birds in the flock for the most efficient utilization of labor, and on many other poultry plants the laying houses and other buildings are poorly arranged, resulting in much wastage of time in caring for the birds.

TABLE 77.—LABOR INCOME IN RELATION TO UTILIZATION OF LABOR
(Putnam, 1935)

Gross receipts per $1 labor cost	No. of farms	Labor income per flock
Below $3.00	11	$ 137
$3.00 to 3.99	13	955
4.00 to 4.99	9	1,346
5.00 to 5.99	7	2,315
6.00 and over	9	4,516

Efficient Utilization of Investment.—In the expansion of the poultry industry of the United States too many poultry plants have gone on the rocks shortly after being started because of unwise investment in buildings and other items that were much more expensive than justified. Overhead costs, such as taxes, interest, insurance, depreciation, repairs, and upkeep on these plants, were excessive. These fixed costs also become excessive when a poultry plant is not developed or operated on the most efficient basis possible. Practically all of the fixed costs remain in full effect even when one-half or more of the poultry plant is idle.

In the Connecticut survey it was found that the cash sales per $1 investment proved to be a better measure of successful operation in obtaining a satisfactory labor income from the flock than overhead costs per bird. Sales per $1 investment take into account the relative capacity at which the plant is operated.

TABLE 78.—LABOR INCOME IN RELATION TO UTILIZATION OF INVESTMENT
(Putnam 1935)

Cash sales per $1 investment	No. of farms	Labor income per flock
Over $0.80	10	$4.406
$0.60 to $0.80	17	1.421
0.40 to 0.59	13	1.189
0.20 to 0.39	6	0.501
Under 20	3	−1.258

Unwise original investment and high overhead costs are the cause of low earning capacity of many poultry plants. The problem of securing full utilization of investment and reducing overhead costs is accomplished by developing a business organization that will provide a good labor income if operated efficiently. This means increasing the size of the business on many poultry plants.

Sufficient Size of Business.—A poultry business of sufficient size provides for the most efficient utilization of labor and investment and,

furthermore, makes it possible to secure top prices for graded products because of the volume of products that makes grading possible. The results of the Connecticut survey show that few poultry flocks having a small volume of business were able to utilize either labor or investment efficiently. It was also found, however, that not all large-scale businesses utilized their labor or investment most efficiently. On the average, the larger the volume of business the greater was the labor income.

TABLE 79.—LABOR INCOME IN RELATION TO VOLUME OF BUSINESS (Putnam, 1935)

Volume of business	No. of farms	Labor income per flock
Below $4,000	16	$ 247
$4,000 to 5,999	14	1,445
6,000 to 7,999	7	1,457
8,000 to 9,999	2	1,689
10,000 and over	10	4,506

The size of a business is increased by enlarging the size of the flock. Volume of business can be increased by securing better egg production. The earnings of the business can be increased in different ways: (1) by selling market eggs retail instead of wholesale, if the situation permits; (2) by selling through an egg and poultry auction; (3) by selling hatching eggs and baby chicks; and (4) by selling breeding stock. When eggs are sold at wholesale prices it appears that a one-man flock unit should consist of approximately 1,500 layers. Where baby chicks and breeding stock, in addition to market eggs, are sold the size of the flock may consist of approximately 800 birds.

Among the Connecticut poultry farms it was found that where the market eggs were sold wholesale, the average cash sales per $1 investment amounted to 49 cts.; where eggs were sold retail or hatching eggs were sold, the average cash sales per $1 investment was 58 cts.; where baby chicks and breeding stock were sold in addition to market eggs, the average cash sales per $1 investment was 91 cts.

Six Factors for Efficient Management.—The six factors, annual egg production, October and November egg production, laying-flock mortality, utilization of labor, utilization of investment, and size of business, are good measures of efficient management. An operator may be efficient as measured by three of these factors but deficient when measured by the other three factors. Seven of the Connecticut poultry farms were found to be below the average in all six factors, with the result that the average labor income was minus $300. Seven other poultry farms were found to be above the average in all six factors, and these farms had an average

labor income of $4,516. Inefficient management in all six factors cost the first seven operators $4,816, on the average.

TABLE 80.—LABOR INCOME IN RELATION TO EFFICIENCY AMONG SIX FACTORS (Putnam, 1935)

No. of factors in which farms excelled	No. of farms	Labor income per flock
None	7	−$ 300
1	7	734
2	9	1223
3	10	1247
4	5	2209
5	4	3431
6	7	4516

It is clearly apparent from the foregoing data that it is possible for any poultrymen to make changes and perfect the organization of their usiness, thereby increasing their labor income. It is first necessary to evelop a good business organization, and then the organization must be perated as efficiently as possible in order to secure the greatest possible utilization of labor and investment. The competition in the production of market eggs that will command best prices and yield the greatest profits is becoming keener each year, and in order to stay in the business and make a good living those engaged in the business must become increasingly competent.

Importance of Egg and Feed Prices.—The influence of various factors that are under the control of the poultryman in determining labor income has been discussed. It is important now to consider the influence on labor income of some important factors over which the poultryman has very little control. By and large, he is obliged to accept the established price for the grade of eggs offered and must pay the prevailing price for feed.

A poultryman may be an efficient manager and secure good production but be a poor salesman and not sell his product to best advantage. Likewise, a poultryman may not purchase his feed to best advantage. Good salesmanship in selling market eggs and ability to purchase a well-balanced diet at least cost are very important factors in determining the labor income obtained.

It has been pointed out previously that the cost of feed is the most important single cost factor in producing eggs, amounting to one-half or more of the total costs on many poultry plants. High feed costs and low egg prices mean relatively low labor income even under the most efficient methods of management.

The feed:egg price ratio has an important bearing on the expansion or contraction of the poultry business from year to year and from season to season. Relatively high feed costs are naturally unfavorable for egg production, whereas relatively low ones are favorable.

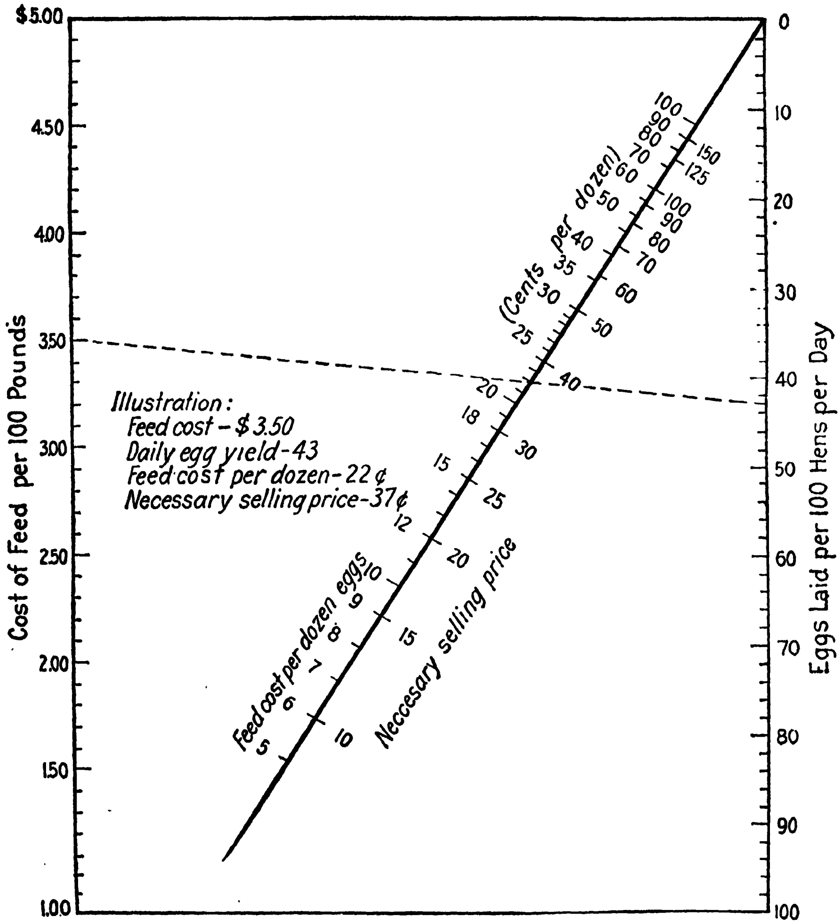

FIG. 210.—Calculation of feed cost per dozen and necessary selling price at varying feed prices and at various levels of egg production. It is assumed that 100 hens will consume 22.5 lb. of feed per day and that feed cost is 60 per cent of the total cost of production. (*Card*, 1929.)

When feed prices are relatively high and average egg prices relatively low, it is most important for the poultryman to purchase his feed as economically as possible without sacrificing its egg-producing value. Moreover, efficient poultrymen usually secure a premium for their eggs. With a flock of 1,000 layers, averaging 150 eggs each, a saving of $3 per ton on a good egg-producing diet and a premium of 1 cts. per dozen would increase the labor income from the flock by $250.

ECONOMIC FACTORS IN MARKETING

The costs of marketing poultry and poultry products have an important bearing on prices paid to producers and on those paid by consumers. The distributor has a legitimate function to perform and is entitled to a

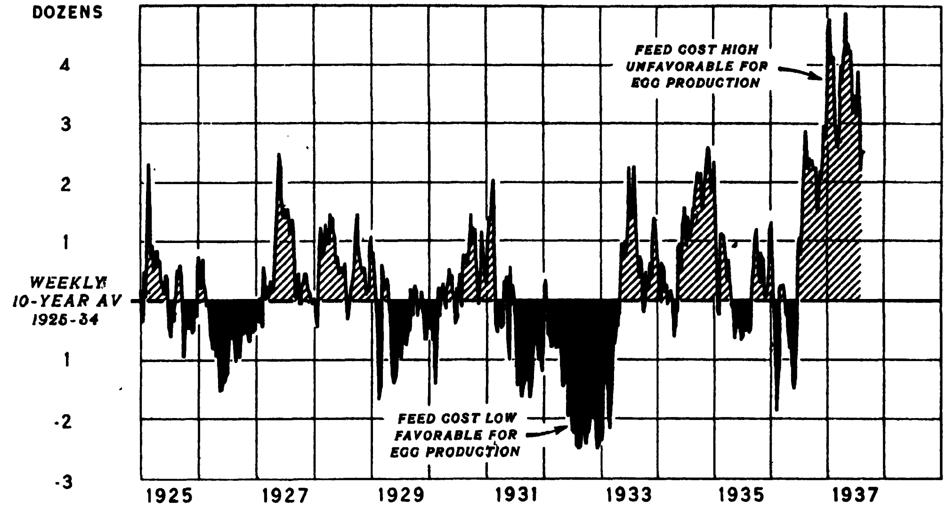

FIG. 211.—The feed: egg price ratio measures the relationship between feed costs and egg prices. Since feed costs are by far the most important costs of egg production, this relationship is perhaps the most important forecasting device available with respect to the poultry industry.

When the feed: egg ratio is above average (high) it indicates that feed costs are high and to the producer of eggs the situation is unfavorable. Under this circumstance curtailment of egg production is to be expected, the evidence of which appears in several forms. Close culling of laying flocks and heavy marketing of fowl are one evidence of curtailment. A decrease in the number of chicks hatched also reflects the effect of the unfavorable situation on the producers' plans to maintain laying flocks by replacement of hens with pullets.

A low feed: egg ratio shows low feed costs relative to egg prices, and a favorable situation for egg producers. More liberal feeding is likely to increase production per hen. Culling is relaxed and marketings of fowl less heavy, especially out of season. Heavy hatchings for replacement reflect the intention of the producer to maintain the laying flocks both in numbers and efficiency.

The feed: egg price ratio is calculated weekly from prices quoted at wholesale. Feed prices are in carlots at or near Chicago and include mostly corn and wheat, but barley, bran, and tankage are added, the latter to reflect the cost of animal protein. Although producers do not all use this diet either as to ingredients or the proportions here used for their combination, this group does reflect general changes in feed costs. Egg prices are for fresh graded Firsts at Chicago. This ratio does not represent actual farm conditions but its changes do show changes in the situation on farms in the important egg and poultry producing area in the Northcentral states and more generally for the country as a whole. (*U. S. Dept. Agr.*)

fair profit for his services. Excessive costs in distribution, however, are harmful because they result in lower prices being paid to producers and higher charges being paid by consumers. For the most part, consumers are willing to pay a relatively good price for poultry products of superior quality, but excessive charges tend to curtail consumption.

Although the producer has little control over the prices of poultry and poultry products, he can do a great deal to reduce marketing costs by offering on the market only superior quality products. Selling to the distributor eggs that spoil under the best conditions of transportation and storage and selling thin, scrawny, and emaciated poultry increase

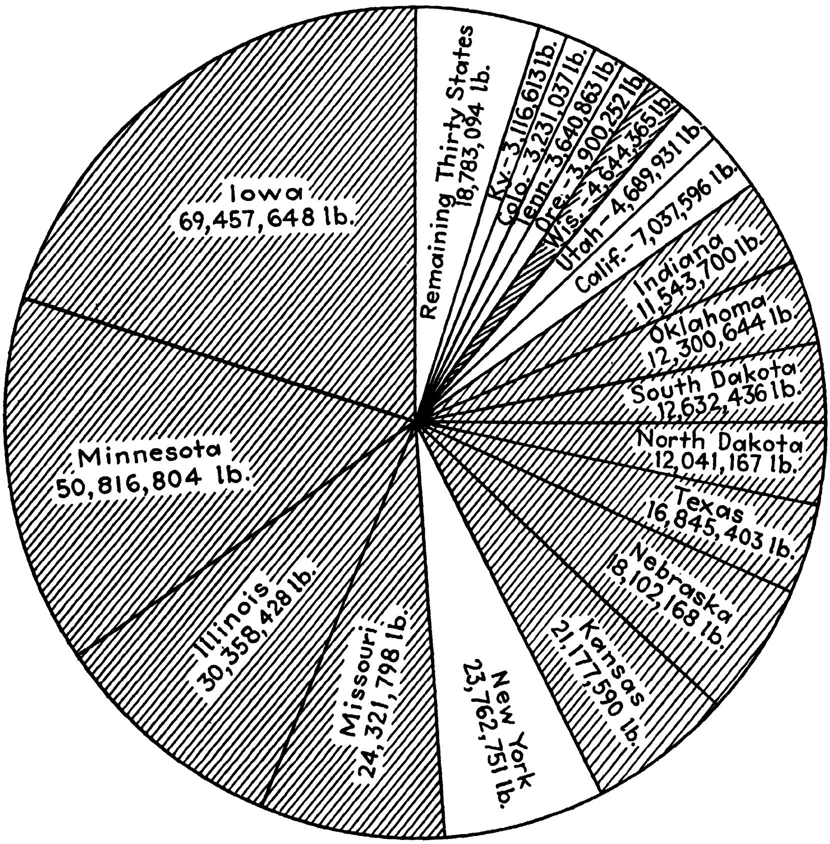

FIG. 212.—The middlewestern states and Texas supplied about 81 per cent of the dressed poultry received at the New York, Boston, Philadelphia, and Chicago markets in 1936. In classifying the receipts, the earliest point of origin shown in the billing is used. Shipments stored in transit which on reshipment show the first point of origin would therefore be classified correctly. Since some lots are reshipped but are shown as originating at intermediate points, the figures on which this chart is based include some intermarket shipments. The classification is thought to be a fair indication of the real origin of dressed poultry arriving at the four markets. Distance from the consuming centers adds to shipping costs. (*U. S. Egg and Poul. Mag.*)

the costs of marketing and lower the average price for all products paid to the producer. Moreover, the marketing of low-grade products tends to decrease consumption, which is not to the producers' best interests.

The shipping charges and handling expenses comprise the principal costs in marketing, the greater the distance a product has to be shipped the greater being the costs in marketing. The industrial East, comprising

such important consuming centers as New York, Philadelphia, Boston, and many other cities, constitutes the dominant egg and poultry markets. Poultry and poultry products produced in areas adjacent to these important consuming centers enjoy a distinct advantage from the standpoint of price and cost in marketing.

On the other hand, poultry and poultry products can be produced more cheaply on the average in the corn and wheat belts, where grain is less expensive than in other sections. It is possible, therefore, for producers in the Middle West to receive less for their products and still compete successfully with producers in the Northeast and on the Pacific Coast. The latter two regions must of necessity strive to produce a superior quality of product which will command a better price if they are to stay in business.

There are very few data on the costs of marketing poultry and poultry products, a fact that is understandable when the complex problems of marketing are taken into consideration.

Officials in the U. S. Department of Agriculture have estimated that the poultry producer receives approximately 66 per cent of the price that the consumer pays for eggs. Eggs are marketed in so many different ways that it is impossible to give marketing cost data for each of the different ways. The data in the accompanying table, giving the costs of marketing eggs by members of the Utah Poultry Producers Cooperative Association, show the relationship that exists among the various cost factors and serve to illustrate the approximate cost of marketing eggs from the Middlewest and other surplus-producing areas.

TABLE 81.—DISTRIBUTION OF AVERAGE COSTS OF MARKETING UTAH EGGS, PER CASE AND PER DOZEN, IN NEW YORK CITY, DECEMBER, 1936
(Scanlan, 1937)

Item	Marketing costs	
	Per case, dollars	Per dozen, cents
Association overhead	.14	.46
Station costs	.34	1.13
Cases, flats, and fillers	.40	1.33
Shipping	1.19	3.97
Selling	.20	.67
Total	2.27	7.56

When eggs are placed in storage the costs in cents per dozen have been estimated as follows: warehouse rental 1.2 cts.; interest 1.2 cts.; insurance, 0.3 cts

The costs of marketing poultry are relatively greater than those of marketing eggs. It has been observed, for instance, that in the marketing of live poultry in New York City certain marketing charges are excessive because of the abnormal conditions prevailing in the distribution of live poultry from the time it arrives at the terminal market.

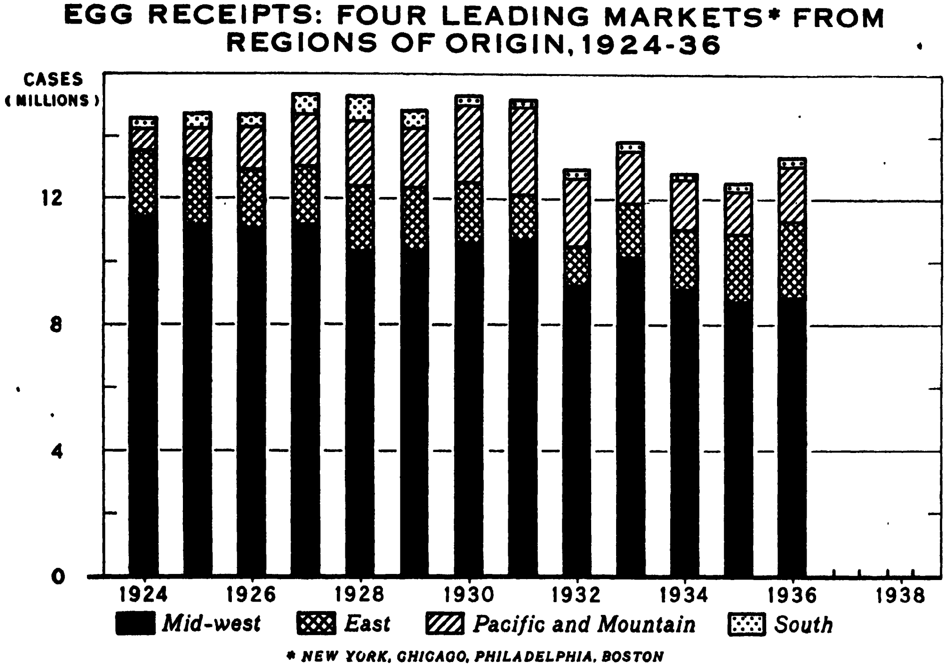

FIG. 213.—Receipts at the New York, Boston, Philadelphia, and Chicago markets show the volume of eggs flowing through market channels at these four markets from regions of origin, 1924–1936. They do not show sales made direct from producer to consumer or to retailer and therefore are not to be considered as total sales or total production. The Middle West is the most important source of eggs for these markets, but the East has been supplying an increasing proportion during the last 4 years. At the same time there has been a tendency for receipts from the Middle West and the Mountain and Pacific areas to decline. Falling prices made freight rates very burdensome and discouraged production in these areas at some distance from the market. (*U. S. Dept. Agr.*)

The estimated cost, given in Table 82 of marketing live and dressed poultry produced in Missouri and sold retail in New York City gives some conception of the different cost factors involved.

A simple illustration may be given to emphasize the complicating factors involved in marketing live poultry. In a comprehensive study of the marketing of broilers produced in Maryland it was found that broiler operators who shipped live broilers on consignment incurred marketing costs equivalent to approximately 5 per cent of their total operating expenses. These marketing costs included various items, the percentage that each contributed to the total cost of marketing being as follows: commission charges, 38.5; shrinkage, 35.9; transportation, 22.4;

labor, 1.9; the cost of crates and loss from death, 1.3. This is a good illustration of the ramifications involved in the marketing of live poultry.

The total cost of marketing the various classes of dressed poultry is somewhat higher than is the cost of marketing eggs, and has been estimated as nearly 50 per cent of the retail price. Officials of the U. S. Department of Agriculture have estimated that producers receive on the average 57 per cent of the retail price of fowl.

TABLE 82.—ESTIMATED COST OF MARKETING POULTRY FROM PRODUCERS IN MISSOURI TO RETAIL IN NEW YORK CITY[1]
(Sprague, Sturgess, and Radabauch, 1937)

Item	Cost of marketing per pound, cents	
	Live poultry	Dressed poultry
Procurement cost, buying and trucking	2.0	2.0
Cost of country-plant operation, including shrinkage	0.6	5.0
Cost of package	....	0.5
Freight	1.8	1.4
Carman	0.5	
Feed	0.6	
Unloading, including storage for dressed poultry	0.3	0.3
Coops	0.4	
Trucking at New York City	0.3	
Commission	1.0	0.5
Slaughtering, including shrinkage and trucking	4.0	0.2
Delivery and bad debts	0.5	0.3
Total	12.0	10.2

[1] Data in this table were compiled from actual cost figures, questionnaires to shippers, and information received from shippers and plant operators.

The possibility of the producer's receiving a greater share of the consumer's dollar will be increased by the extent to which there is a general improvement in the quality of poultry and poultry products offered for market and by the extent to which increased efficiency is developed in the various marketing and processing practices.

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AGRICULTURAL COLLEGES AND EXPERIMENT STATIONS IN THE UNITED STATES AND CANADA

Much of the material in this book is based upon the results of research carried on at the various state experiment stations and other public institutions, especially in the United States and Canada. Many of these institutions are referred to in the context. Since it is highly probable that some readers of this book would like to write the institutions for further information along certain lines, this list of institutions with their addresses has been prepared. Except where noted, the state experiment stations in the United States are at the colleges of agriculture.

United States

Alabama: College of Agriculture, Auburn.
Arizona: College of Agriculture, Tucson.
Arkansas: College of Agriculture, Fayetteville.
California: College of Agriculture, Berkeley.
Colorado: College of Agriculture, Fort Collins.
Connecticut: College of Agriculture, Storrs.
Delaware: College of Agriculture, Newark.
Florida: College of Agriculture, Gainesville.
Georgia: College of Agriculture, Athens.
Idaho: College of Agriculture, Moscow.
Illinois: College of Agriculture, Urbana.
Indiana: College of Agriculture, Lafayette.
Iowa: College of Agriculture, Ames.
Kansas: College of Agriculture, Manhattan.
Kentucky: College of Agriculture, Lexington.
Louisiana: College of Agriculture, Baton Rouge.
Maine: College of Agriculture, Orono.
Maryland: College of Agriculture, College Park.
Massachusetts: College of Agriculture, Amherst.
Michigan: College of Agriculture, East Lansing.
Minnesota: College of Agriculture, St. Paul.
Mississippi: College of Agriculture, State College.
Missouri: College of Agriculture, Columbia.
Missouri: Poultry Experiment Station, Mountain Grove.
Montana: College of Agriculture, Bozeman.
Nebraska: College of Agriculture, Lincoln.
Nevada: College of Agriculture, Reno.
New Hampshire: College of Agriculture, Durham.
New Jersey: College of Agriculture, New Brunswick.
New Mexico: College of Agriculture, State College.
New York: College of Agriculture, Ithaca.
North Carolina: College of Agriculture, Raleigh.

North Dakota: College of Agriculture, Fargo.
Ohio: College of Agriculture, Columbus.
Ohio: Experiment Station, Wooster.
Oklahoma: College of Agriculture, Stillwater.
Oregon: College of Agriculture, Corvallis.
Pennsylvania: College of Agriculture, State College.
Rhode Island: College of Agriculture, Kingston.
South Carolina: College of Agriculture, Clemson.
South Dakota: College of Agriculture, Brookings.
Tennessee: College of Agriculture, Knoxville.
Texas: College of Agriculture, College Station.
Utah: College of Agriculture, Logan.
Vermont: College of Agriculture, Burlington.
Virginia: College of Agriculture, Blacksburg.
Washington: College of Agriculture, Pullman.
Washington: Western Washington Experiment Station, Puyallup.
West Virginia: College of Agriculture, Morgantown.
Wisconsin: College of Agriculture, Madison.
Wyoming: College of Agriculture, Laramie.

United States Department of Agriculture, Washington, D. C.
National Agricultural Research Center, Beltsville, Maryland.

Canada

Alberta: College of Agriculture, Edmonton.
British Columbia: College of Agriculture, Vancouver.
Manitoba: College of Agriculture, Winnipeg.
Nova Scotia: College of Agriculture, Truro.
Ontario: College of Agriculture, Guelph.
Quebec: Macdonald College, Macdonald College.
Saskatchewan: College of Agriculture, Saskatoon.
Dominion Department of Agriculture, Ottawa.

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Anatomical Record. Philadelphia.
Biochemical Abstracts. Philadelphia.
Biochemical Journal. London.
Biological Abstracts. Philadelphia.
Biological Bulletin. Woods Hole, Mass.
Canadian Journal of Research. Ottawa.
Endocrinology. Los Angeles, Calif.
Experiment Station Record. Washington, D. C.
Genetics. Brooklyn, N. Y.
Hilgardia. Berkeley, Calif.
International Review of Poultry Science. Rotterdam.
Journal of Agricultural Research. Washington, D. C.
Journal of Agricultural Science. London.
Journal of the American Veterinary Medical Association. Chicago.
Journal of Bacteriology. Baltimore.
Journal of Biological Chemistry. Baltimore.
Journal of Economic Entomology. Geneva, N. Y.
Journal of Experimental Biology. London.
Journal of Experimental Zoölogy. Philadelphia.
Journal of General Physiology. Baltimore.
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